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BRITISH COLONIAL DEVELOPMENT*

The announcement by Mr. Creech Jones in the House of Commons of the British Government's proposal to establish a Colonial Development Corporation marks a definite stage towards the establishment of a new Colonial system aimed at raising the standard of living in British Colonies, which has been implicit in such recent proposals as Dr. E. B. Worthington's Development Plan for Uganda, and the plan for the production of groundnuts in East Africa. The Groundnut Corporation Scheme is concerned primarily with foodstuffs; but its contribution to the raising of the standard of living in Tanganyika, Northern Rhodesia and Kenya may well far outshadow its contribution towards meeting the world shortage of fats. The £25,000,000 required for this Corporation is indeed to be provided separately; but it will none the less be as distinct a contribution to Colonial Welfare as the capital of £100,000,000 of the Colonial Development Corporation now announced.

Mr. Creech Jones said that the Corporation would operate on commercial principles, and that its object would be to establish or assist any enterprise in the Colonies which is designed to increase their general productive capacity. While these enterprises might be mainly agricultural, the Corporation would be able to undertake any enterprise which served the general object either itself, or through subsidiary organisations for individual projects, or by assisting existing enterprises. Unlike the Development Board for the Colonies canvassed unofficially a few years ago, the new Corporation will be subordinate both to the Colonial Office and the Colonial Governments. The intention is that the Corporation and its subsidiaries should operate generally in close consultation with Colonial Governments, to ensure that their activities are conducted in the way best suited to promote the welfare of the Colonial peoples.

It was made clear that the Corporation is intended to supplement, not supplant, private enterprise. The Government would continue its policy of encouraging public utilities and other suitable forms of public enterprise; but it would also welcome private enterprise and investment so long as they are in harmony with the plans of Colonial Governments for social and economic development. Mr. Creech Jones, in reply to questions, indicated that the Government is alive to the importance of decentralization, and that although the head office must be in London, certain concerns and enterprises would have their principal offices in the territories with which they are strictly concerned.

* Abridged from *Nature*, 160 : 171-173, 1947.

The scheme as outlined by Mr. Creech Jones is thus based on the realization that capital on a far larger scale than is made available under the Colonial Development and Welfare Act is needed to raise the standard of living in the British Colonial Empire. What is equally important, there appears to be visualized co-operation with other Government departments besides the Colonial Office, such as the Board of Trade and the Ministry of Food. Several Departments are in fact already working together on a survey of opportunities for new commodity production in the Colonial Empire. Success may largely depend on the extent to which there is stimulated on a much larger scale that two-way flow of ideals, already to be seen on a modest scale, resulting from the work of the Colonial Research Committee and the Colonial Products Research Council. It will certainly depend largely on the extent to which there is secured the co-operation of scientific workers in the way that is so conspicuously a feature both of the groundnuts project for East Africa and the development plan advanced by Dr. E. B. Worthington for Uganda. The feature of Dr. Worthington's plan is the suggestion that pilot development schemes should be used to try out ideas of land use and social services which later can be applied to large parts of the protectorate. They should also be areas of intensive production, at first by State enterprise, in country which is at present largely undeveloped. In this way, Dr. Worthington contends, about twice as much expenditure on public services per head of population as is possible in the country as a whole will pay dividends after ten years.

Dr. Worthington recognises and states the fundamental problem in Colonial development and welfare which the general schemes under the new Corporation will equally have to face. The average standard of living cannot rise and public services cannot expand unless production increases at a greater rate than population. Ten years, he suggests, should be devoted to a production drive while increasing social services, at a rate greater than population increase. If success is achieved, Uganda will be able to support mass education and a mass health scheme during the following decennium.

In the production drive, the great asset of Uganda is not man-power but undeveloped land and water. The chief factors which limit development are the lack of fundamental information about the country and the people; a system of production incompatible with the full use of natural resources; lack of capacity of the African for physical work; and power based on the most inefficient of fuels. Dr. Worthington's plan aims at solving the fundamental problem of balance between population and production by reducing these limiting factors, although he is doubtful whether adequate results can be achieved without some degree of compulsion, possibly the equivalent of that which is applied in Britain to-day.

The pilot schemes suggested are for the development of a self-contained piece of land, preferably a catchment area of say 500 square miles, sparsely inhabited on account of tsetse fly. Settlers up to 6,000 families would be employed for the first few years, while the whole area was being developed as a Government estate. At this stage there would be only six Europeans as against 42 Europeans to about 1,800 Africans in the resident units of the groundnut scheme. Later, most of the settlers would become tenant farmers under close supervision, a part of the unit being retained as a Government farm. Initial clearing and subsequent cultivation would be undertaken with mechanical assistance, where possible. Communications, forestry, water-control, agriculture, fisheries and social services would be organised for the efficient development of land, water and people, with an emphasis on productive services.

The scheme is finely conceived and represents a scientific approach that might well be adopted more widely. It is not only in research in applied biology, in animal husbandry, forestry, fisheries, hydrology, meteorology, agriculture and the like that science can contribute so much to Colonial development and welfare. It is becoming more and more clear that the scientific approach is the only one that holds out real hope of a solution to the all-important human problem. Although Dr. Worthington makes like reference to the contribution of the social sciences, his scheme, like the groundnut scheme, is in keeping with the idea that Mr. Aldous Huxley outlines in his recent book, "Science, Liberty and Peace," of developing regional self-sufficiency as a decentralizing and stabilizing factor in world order. It is equally in line with ideas which Col. W. R. Crocker emphasises in his penetrating commentary 'On Governing Colonies,' of concentrating less on what is ideal from the point of view and more on what is practical from that of the African, on the preventive rather than the remedial aspect of public health and the essential idea of the Tennesse Valley Authority, in which the association of the ordinary people affected by the scheme is first secured. Similar ideas are stressed by Sir J. Hawthorn Hall, the Governor of Uganda, in some notes on the economic development of Uganda which preface Dr. Worthington's report.

That the regional aspect is present in the mind of the Colonial Secretary is shown by his recent comments on the eighteen months work of the Colonial Economic and Development Council. Nearly all the 35 territories concerned have submitted ten-year development plans, although some plans have been referred back with comments or suggestions. But Mr. Creech Jones has stressed the importance of regional planning and development in contiguous Colonial territories such as East, Central and West Africa, and also in the West Indies. In a memorandum on closer association of the British West Indian Colonies, he refers to the manifest need in all the Colonies concerned for improved facilities for research, including surveys and statistical services, in order that plans for economic development and social welfare may be soundly conceived and wisely executed. Except in co-operation, the Colonies will not generally be able to afford or fully to employ the services of the experts required to fulfil those functions. It was announced that a conference is to be held at Montego Bay, Jamaica, in September, and its outcome will be watched with great interest by all who are aware of

the potentialities which have already been revealed in the Caribbean. There are other aspects of the man-power situation which are of fundamental importance in all these proposals. Inevitably the formation of a Colonial Development Corporation, like the Groundnut Corporation, with its various subsidiary schemes and ramifications, tends to widen the range of opportunities which the Colonial Service offers and to call for more varied abilities among the members of that service. No thoughtful reader of Col. Crocker's recent comparative study of British, French, Belgian and other Colonial practice and experience can doubt the need for recruits of high quality to the Colonial Service, the great scope for initiative and responsibility which that service offers, or the need for a new outlook in some quarters and for drastic changes in organisation, practice and the transfer and promotion of staff. Ultimately, it is on the quality of the staff by which the Development and Welfare Schemes are administered, their vision and understanding of the needs and minds of the native peoples, their appreciation of the contribution of science, of the problems and opportunities of the private and public corporations seeking to serve the needs of the native peoples and of the world, that success will depend. Nor will the ablest men and women be forthcoming and their zeal and enthusiasm maintained unimpaired unless the conditions of service are such as to call forth their best efforts and to give them the continued stimulus and incentive that will spring from manifest participation in the high task not merely of serving the material and social needs of the Colonial peoples, but even more of training, inspiring and guiding their future leaders in accordance with those new conceptions of imperial responsibility which mark the third Colonial Empire now developing. It should be a first pre-occupation of the Government to see that no timidities or inhibitions of Colonial administration are allowed to hinder the full use of all the expert knowledge of Colonial resources and methods of treatment that have been accumulating in the last four years, or the vigorous prosecution of the fresh researches still required. Above all, nothing must be allowed to frustrate the boldness of imagination with which these new opportunities must be served.

WAR ON WEEDS

Herbicides are divided into the following groups :—

(1) Soil sterilants such as sodium arsenite, ammonium thiocyanate, borax or borate ores, carbon bisulphide, chloropicrin and sodium chloride. For killing deep-rooted perennials, 250 lb. of sodium chloride + 15-30 lb. of borax + 3-4 lb. of sodium arsenite per square rod are required.

(2) Non-selective contact sprays such as oil, acid and salt derivatives that kill all vegetation above ground. Many contain sodium arsenite alone or combined with sodium chlorate. This is poisonous to livestock and is a fire hazard.

Newer herbicides include (3) selective sprays like sulphuric acid, oils and Sinox which wilt most broad-leaved weeds but leave grains, flax and grasses unaffected. One gallon of sulphuric acid in 50 gallons of water sprays half an acre and kills most weeds rapidly. Sinox, a coal-tar derivative, is used as a spray from aeroplanes. One gallon of Sinox in 120 gallons of water applied at the rate of 80-100 gallons per acre killed only broad-leaved annuals and had little effect on grasses. Flax and peas should not be sprayed with it before reaching 3 inches height and never after bud formation. Alfalfa and red clover developed high resistance to it when 4-6 weeks old. Light-weight oils applied full strength are used for weeding carrots when the crop is less than three inches tall. Members of *Umbelliferae* are tolerant to oil sprays.

(4) Poisons like arsenic trioxide, arsenic trichloride, sodium chlorate, ammonium sulphamate. $\frac{3}{4}$ lb. of ammonium sulphamate in a gallon of water applied at the rate of 1-3 gallons per 100 square feet is more suitable than sodium chlorate. It does not leave the soil sterile for more than a short time and it contains fixed nitrogen which enriches the soil.

(5) The Sizz-weeder produces a hot-airblast which is applied when the cultivated crop has a greater fibre content than the weeds. It destroys the weeds and leaves the crop unharmed.

(6) Hormones such as those known as 2, 4–D and 2, 4, 5–T stimulate abnormal growth which kills the plants. Small doses such as $\frac{1}{4}$ to $\frac{1}{2}$ oz. per square yard are effective. They may be applied in water sprays or incorporated into dust or aerosols. They attack most broad-leaved plants and are most effective on young plants. Plants are killed after about one month. Hormone application should be made within four hours of rain ; it is most effective on plants growing in moist soil and is more rapid in sun than in shade.

(7) Machines for moving and crushing plants, and soil covers to suffocate weed growth. (*Soils and Fertilizers*, 9, 212, 1946.)

COMMONWEALTH AGRICULTURAL BUREAUX

The Executive Council of the Imperial Agricultural Bureaux has decided to change the name of the Bureaux as from January 1, 1948 to Commonwealth Agricultural Bureaux. The Bureaux will continue as hitherto in control of the Institute of Entomology, the Mycological Institute, the Bureaux of Soil Science, Animal Health, Animal Nutrition, Plant Breeding and Genetics, Pastures and Field Crops, Horticulture and Plantation Crops, Animal Breeding and Genetics, Agricultural Parasitology (Helminthology), Forestry, Dairy Science, Biological Control and the South American Potato Collection (*Nature*, 160, 4076, 1947.)

THE WATER AND AIR RELATIONS OF SOME TRINIDAD SUGAR-CANE SOILS PART I

BY

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(I) Introduction

These investigations were undertaken to learn more about the physical properties of contrasted types of sugar-cane soils which control their behaviour on wetting and drying in the field under natural climatic conditions. It was hoped thereby to gain a clearer understanding of the possible effects of tillage, drainage and irrigation on their water and air relations. The number and variety of soil-types utilised for sugar cane growing are legion and no two large areas are occupied by identical soils. Hence the soil of each area needs to be studied strictly on its merits, for generalisations based on experience gained in any one locality cannot be applied unreservedly to another, except in a general way. The idea behind these investigations was therefore to study in detail, both in the field and in the laboratory and over an extended period of time, a limited number of representative samples of sandy and clayey soil-types growing sugar-cane in Trinidad within an area easily accessible from the College.

(II) Failures of the Soils Studied

The locality where these studies were mostly carried out was Field F 88 in the northern part of Caroni Sugar Estate known as Frederick Section. This field comprises sandy soil in its easterly and clayey soil in its westerly parts. The soil-types represented have recently been mapped and named Washington Loams and Cunupia Clays respectively.

The clays "are of estuarine or marine origin and "have largely been derived from the erosion of the "rocks of the Northern and Central Ranges.....A "considerable part of the lower-lying portions..... "are overlain with river or swamp alluvium of more "recent date."‡ The Washington Loams belong to this recent alluvial series; the Cunupia Clays are probably marine and much older.

Drainage: The area was formerly covered with swamp-forest and rain-forest whose removal has caused increased soil erosion. External drainage is poor because of the low-lying flat topography. The area is liable to flooding in the wet season through overflow of the neighbouring Caroni River which carries a large part of the drainage of the high land to the east and north. Internal drainage is said to be generally poor in the clays and partially impeded to free in the sands. Deep borings made within the two parts of Field F 88 proved that the clayey part is uniform in texture at least down to 17 feet below ground-level, whereas the sandy part shows uniform sandy soil only down to the 6-foot depth where the underlying clay formation is entered.

Pedology: Pedological descriptions of the soils, together with laboratory data for their 2-foot profiles, are given in the Appendix.

(III) Moisture and Air Profile Investigations

Profile investigations of moisture and air relations were begun in January, 1943, in Field F 88 which includeed the "good" (sandy) and "bad" (clayey) sugar-cane plots that were once under continuous ecological study as part of the froghopper investigations in 1927-29.

Sampling: Special pits, 2 feet deep, were dug in each of these plots on several occasions during 1943-44. Successive 3-inch layers were sampled with a constant-volume soil-borer so that the distribution of water and air within the pore-spaces of the soil at different times of the year could be ascertained. The data obtained are set out in Table I in which the different sets of results are arranged in order of increasing dryness both for sandy soil and clayey soil. They are also depicted as block diagrams in Figure 1.

Discussion: The main feature of the data in Table I is the great difference between porosity values for the sandy soil and the clayey soil.

Sandy soil: This shows constant porosity at all moisture contents except for a slight change caused by ploughing in May 1943 (No. 4). The non-capillary porosity was solely occupied by air during dry weather (Nos. 3, 4 and 5). In extremely dry weather (No. 6.), when the soil contained no available moisture, the total air-space partly involved the micropores of the colloidal component as well as the macropores. During wet spells (Nos. 1, 2), more than half the non-capillary pore-space was occupied by water which obviously implies impeded drainage. In wet weather, the total air-space was frequently *less than 10 per cent.*, which suggests inadequate aeration and the onset of conditions causing root asphyxiation.

Clayey soil: This shows a diminishing total pore-space as it dries out, doubtless due to colloidal shrinkage. The corresponding increase in apparent specific gravity causes the values for capillary porosity to appear to be too large, since they depend on measurements made on moist plastic soil at sticky point. Hence non-capillary pore-space has negative value for soil that has dried down to about the wilting stage (No. 3) when there is little or no

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‡ A Preliminary Survey of Soil-Types of Sugar Estates of Trinidad; C. F. Charter, Trinidad, 1939.

TABLE I

SEASONAL FLUCTUATIONS OF MOISTURE AND AIR IN THE PROFILE OF SANDY SOIL AND CLAYEY SOIL

(Field F 88, Caroni Sugar Estate)

	Sandy Soil Field F 88: "Good" plot						Clayey Soil Field F 88: "Bad" plot					
Lower depth (ins.)	Total	Pore Space Capillary Vol.	Pore Space Non-Capil. per cent	Moisture Total Vol.	Moisture Avail. percent.	AIR	Total	Pore Space Capillary Vol.	Pore Space Non-Capil per cent	Moisture Total Vol.	Moisture Avail. per cent.	AIR
(1) Wet (8th Jan. 1943)												
3	47	25	22	35	20	12	53	44	9	40	14	13
6	45	24	21	41	27	4	51	43	8	44	18	7
9	41	24	17	37	23	4	50	44	6	45	18	5
12	43	26	17	37	21	6	50	45	5	45	19	5
18	43	25	18	38	23	5	50	49	1	46	17	4
24	43	26	17	39	23	4	50	50	0	46	17	4
(2) Wet (28th July 1944)												
3	47	24	23	36	22	11	53	43	10	39	14	14 (14)
6	45	24	21	35	21	10	51	44	7	45	18	6 (6)
9	42	21	21	34	21	8	49	43	6	45	18	4 (5)
12	45	20	20	36	20	9	50	45	5	40	14	10 (10)
18	43	24	19	36	22	7	50	49	1	42	13	8 (8)
24	42	24	18	33	19	9	50	50	0	43	13	5 (5)
(3) Fairly Dry (1st. Nov. 1944)—after dry spell in wet season												
3	47	21	26	24	11	23	48	56	−8	30	0	18 (28)
6	44	21	23	22	9	22	47	54	−7	33	1	14 (14)
9	41	22	19	26	13	15	47	53	−6	36	4	11 (16)
12	40	22	18	23	10	17	46	55	−9	34	2	12 (13)
18	40	23	17	21	7	19	46	54	−8	35	3	11 (15)
24	40	23	17	23	9	17	45	57	−12	38	4	7 (12)
(4) Medium-Dry (30th Nov. 1943)—after ploughing												
3	50	20	30	19	7	31	48	50	−2	29	0	2 (61)
6	46	22	24	21	8	25	44	50	−6	32	3	9 (11)
9	44	20	24	21	9	23	43	54	−11	34	2	2 (49)
12	39	23	16	25	11	14	42	56	−14	33	2	9 (171)
18	38	23	15	28	14	10	42	56	−14	35	2	9 (15)
24	38	32	15	31	17	7	43	56	−13	38	3	75 (12)
(5) Very Dry (22nd April 1943)												
3	—	—	—	—	—	—	—	—	—	—	—	
6	—	—	—	—	—	—	—	—	—	—	—	
9	—	—	—	—	—	—	45	50	−5	25	0	20 (25)
12	—	—	—	—	—	—	46	49	−3	29	0	17 (21)
18	—	—	—	—	—	—	46	58	−12	33	0	13 (17)
24	—	—	—	—	—	—	42	52	−10	35	4	7 (15)
(6) Extremely Dry (1st Mar. 1944)												
3	47	23	24	7	0	40	—	—	—	—	—	—
6	43	24	19	14	0	29	—	—	—	—	—	—
9	43	25	18	14	0	29	—	—	—	—	—	—
12	39	24	15	16	2	23	52	48	4	27	0	25 (23)
18	38	24	14	20	6	18	40	56	−16	30	0	10 (20)
24	38	26	12	28	12	10	45	53	−8	30	0	15 (20)

FIGURE 1

SOIL CONSTANTS: (i) Total pore-space is derived from apparent specific gravity (D_1) determined by weighing the oven-dried cores obtained by the constant-volume soil-borer, and true specific gravity (D_2) determined by a specific gravity bottle method. $S = \frac{D_2 - D_1}{D_2} \times 100$ per cent.

(ii) *Capillary pore-space* was derived from index of texture value (sticky-point moisture *minus* one-fifth coarse and fine sand content) by multiplying by D_1. Its volume is thought approximately to measure total colloidally-bound water.

(iii) *Non-capillary pore-space* is obtained by difference.

(iv) *Total moisture content* was determined by weighing and drying the borer samples brought to the laboratory in sealed containers.

(v) *Available moisture content* is assessed as the difference between total moisture and wilting coefficient, arbitrarily taken as 0.6 times the capillary pore-space.

(vi) *Air-content* at the time of sampling is given by the difference between total pore-space and moisture content volume.

available moisture present. The marked shrinkage of the clay soil in drying *causes cracks to develop.* These greatly augment the natural non-capillary pore-space which is otherwise very small in the wetted and fully-swollen clay. The figures in brackets represent the total air-space, obtained by assuming that the clay keeps its original total pore-space when fully swollen (No. 1). They may thus be taken as an approximate measure of the total crack-space at different moisture contents. Crack-volume exceeds the 10 per cent. value, arbitrarily chosen as denoting the onset of root asphyxiation, at comparatively high moisture contents (No. 3.) *It is quite as large as the corresponding air-space volume in the sandy soil* under the same field moisture conditions. Thus, because of the facility for cracking, the clayey soil is practically always as well aerated as the sandy soil in dry weather. In wet weather, aeration in the sandy soil is greatly reduced because drainage impedence prevents the complete emptying of the non-capillary pore-spaces of water. Rapid drying out of the soils in the field occurred. The surface was bare and unprotected during a large part of the investigational period. During the early part of the first year (1943), the land was occupied by a sparse first ratoon crop of which only 3 acres could be reaped (in March), giving 3 tons of cane per acre. The land was tractor ploughed in May and left untouched until late July when it was planted up again. The young sprouts only sparsely covered the ground during the dry season of 1944; growth was retarded later by unusually dry weather in August, October and November. Drying out and cracking of the soil were rapid during the dry spells, especially in January, February and March, 1944 (No. 6). The plant-cane crop was reaped in early 1945 and gave 26 tons to the acre for the whole field.

Whilst the two kinds of soil were evidently equally aerated throughout the greater part of the investigational period (the sandy soil because of its natural highly porous nature and the clayey soil because of deep cracking), the moisture status of the sandy soil was generally somewhat superior, since its content of available water (Table I) was always the higher except in very dry weather. The clayey soil dried out more rapidly than the sandy soil as soon as cracks developed.

Conclusions:

The moisture and air profile data for the 2-year period, January, 1943, to November, 1944, show that the degree of aeration is practically the same for sandy soil and clayey soil, being a function of the large non-capillary porosity of the sand and the extensive development of cracks in the clay. Available moisture content is higher in the sand during wet weather, but water absorption by the plant is then probably limited by lack of aeration which causes incipient root-asphyxiation. Both soils dry out rapidly during dry weather but the clay soil reaches wilting point first because of the greatly enhanced rate of drying induced by the development of cracks.

(IV) Soil Moisture and Air Fluctuations

The rather unexpected results described in the last section were obtained during successive visits paid once every four months for two years. It would be interesting to know what the fluctuations over shorter intervals of time might be. Evidence of this fortunately may be adduced from periodic soil-moisture data collected *once a week* at the same sites in 1927 and 1928. On these occasions, topsoil down to 12 ins. and subsoil, 12—24 ins., were sampled and their moisture contents were recorded as weight percentages. The porosity values obtained later at the same sites and discussed in the last section may now be applied to these data so that volume relations for moisture and air may be derived therefrom. The results obtained are depicted in Figure 2 which shows the volume fluctuations of soil moisture and soil air for each soil layer separately. The plots of each soil-type were growing a poor stand of second ratoons for most of 1927 and of plant-canes in 1928. Rainfall data for the period of this investigation, as well as for the last for comparison, are given in Table II.

TABLE II

Rainfall Data: Caroni Estate

	Dry season					Total	Wet season							Total	Grand Total
	Jan.	Feb.	Mar.	Apr.	May		June	July	Aug.	Sept.	Oct.	Nov.	Dec.		
31 yrs. (1926-1945)	3.0	1.4	1.5	2.4	6.2	14.5	10.2	10.1	10.7	8.8	8.1	8.7	7.1	63.7	78.2
1945...	0.6	1.9	2.1	5.2	3.3	13.1	17.2	8.4	11.9	13.8	8.7	11.7	5.3	77.0	90.1
1944...	1.9	0.0	1.9	2.5	10.5	16.8	24.0	11.1	8.7	9.4	3.2	7.1	7.2	70.0	87.5
1943...	7.2	0.6	1.2	2.3	14.2	25.5	4.5	12.2	11.0	4.0	9.3	4.1	5.5	50.6	76.1
1928...	5.1	0.5	0.7	2.4	2.1	10.8	7.7	6.8	7.0	5.6	5.8	11.3	5.7	49.9	60.7
1927...	6.2	7.6	1.6	9.6	7.6	32.6	13.1	8.2	9.8	11.6	8.4	5.7	5.6	62.4	95.0

The dry season of 1927 was exceptionally rainy, more than twice as much rain falling than in the dry season of an average year. The only dry month was March. By contrast, the dry season of 1928 was unusually dry. The total dry season rainfall of 1928 was only one-third that of the dry season of 1927. The wet season of 1928 was also rather dry, the rainfall of each month (except November) being only about two-thirds normal.

Discussion: The differential effects of the variable intensities and distribution of the rainfall on the magnitudes of the moisture and air contents of the two contrasted soils are shown in the diagram (Figure 2). The main results may be described thus :—

Sandy soil: The moisture content during the 1927 rather rainy dry season, both for the first and the second foot layers, never approached nearer wilting point than 10 or 13 per cent., nor did it ever fall below the non-capillary level. Hence aeration was mostly well above 10 per cent. throughout the whole period, which means that the sugar-cane roots were seldom subject to oxygen deficiency. During the first wet season (which was quite normal), conditions seem to have been highly satisfactory in the upper foot layer; for most of the time there was sufficient available water and air to meet the requirements of the cane crop, despite the fairly heavy rainfall. The second foot layer, however, contained insufficient air at all times. Evidently the under-drainage* in this soil is not free nor rapid enough fully to cope with normal wet season rains.

The second dry season (1928), being abnormally dry from February onwards, caused the moisture content to approach much nearer the wilting level, falling to within 3 per cent. of it in the top foot layer and within 9 per cent. in the second foot layer. For a large part of the time the air-space involved the colloidal or capillary pores and was often excessive in amount. There was always some available water present, however, especially in the second foot layer, although the crop probably suffered water shortage for nearly 17 successive weeks during this period, except insofar as it could obtain water by means of its deeper roots. Conditions gradually improved as the second wet season progressed; they were fairly satisfactory during July and August.

Clayey Soil: In this soil, conditions during the whole of the first year (1927) were most unsatisfactory. Only for about 3 weeks, in March—April, was aeration adequate. For the rest of the time, sugar-cane roots probably suffered incipient asphyxiation. Both the top foot and the second foot layers were practically waterlogged for the greater part of the year.

By contrast, during the second year (1928), the clay soil was relatively dry for about 18 weeks out of the 34 covered by the records, and aeration was more than adequate for 22 weeks. The wilting point was reached in both the top and the second foot layers in late March, 1928, and from then on to the end of May, the moisture content approached wilting on several occasions. The soil must therefore have been deeply cracked during this time. The moisture in the second foot layer never dried out so much as it did in the top foot though its fluctuations closely followed those of the upper layer. Thus the clayey soil was over-aerated in 1928, just as much as was the sandy soil or even more, and the only important difference in their water relations was that the clayey soil throughout contained a little more available water than the sand during the wet year (1927) while the reverse was the case during the dry year (1928).

In Table III, are given the percentage number of times a certain free air-space occurred within each of the two layers of sandy and clayey soil when soil samples were taken during the two periods, 1st January to 31st August, 1927, and 1st January to 31st August, 1928.

TABLE III

FLUCTUATIONS OF MOISTURE AND AIR: SANDY SOIL v. CLAYEY SOIL

Soil	Year	Weather	Degree of aeration: Free air-space: volume per cent.						Summary	
			0-5	6-10	11-15	16-20	21-25	26-30	Less than 10%	More than 10%
			Percentage of number of times occurring							
SANDY SOIL										
Top foot		Wet dry season ...	3	48	40	9	0	0	51	95
Second foot	1927	Normal wet season ...	25	60	15	0	0	0	85	41
Top foot		Dry dry season ...	0	10	22	42	11	15	10	90
Second foot	1928	Dry wet season ...	10	21	37	32	0	0	31	69
CLAYEY SOIL										
Top foot		Wet dry season ...	70	21	6	3	0	0	91	9
Second foot	1927	Normal wet season ...	82	15	3	0	0	0	97	3
Top foot		Dry dry season ...	5	11	21	26	26	11	16	84
Second foot	1928	Dry wet season ...	10	26	32	21	11	0	36	64

* During the height of the wet season, the water-table in the sandy area frequently rose to within 30 inches of the surface at the highest point of the cane beds, as proved by actual auger borings. This is accounted for by the presence of the underlying impervious clay below the 6-foot level.

Conclusions: The data in Table III substantiate the finding that the *sandy soil* exhibits superior aeration at all times, but they also reveal the fact that, during a wet year (such as 1927), this soil, because of the presence of an impervious underlayer, suffers partial waterlogging, especially in the second foot layer, so that the free air-space on a large number of occasions is inadequate. Under similar wet conditions, the *clayey soil* is evidently almost continuously waterlogged, both in the top foot layer and in the second foot layer; root asphyxiation must then occur and a condition of "physiological drought" must prevail.

During a dry year (for example, 1928), the differences between the moisture and air contents of the sandy and the clayey soils are very small; both are adequately but excessively aerated for long periods at a time and water-shortage must consequently ensue. The plants must then suffer from true or "physical" drought. In the case of the clay soil, the high degree of aeration in dry weather can only be explained by postulating the development of extensive and deep cracks, as in the case of the profile investigations described in the last section.

Yields: The effects of the contrasted soil conditions in the two plots are shown in the yields of sugar-cane, as follows:—

	Sandy soil	*Clayey soil*
	(Tons per acre)	
Grown in wet year, 1927 (Second ratoons)	14.9	3.8
Grown in dry year, 1928 (Plant-canes)	22.5	7.3
Grown in normal year, 1944 (Plant-canes)	25.8	
Grown in normal year, 1945 (First ratoons)	28.4	

The very low relative yield for the clayey soil in 1927 may be attributed to the continuous waterlogging and the low yields for both soils growing plant-canes in 1928 to general drought conditions. By contrast, in 1944 when rainfall was normal, plant-canes gave a much higher average yield for the whole field (the plots were not separately reaped). Although a higher-yielding variety was grown in 1944, the greater production in that year cannot be attributed solely to this fact.

Relationship of soil moisture and air fluctuations to rainfall: It is very evident from the results recorded in this and the last section that the moisture and air relations of the particular sandy and clayey soils under detailed investigation depend on the intrinsic physical properties and specific behaviour of the two contrasted soils when exposed to variable rainfall. This relationship is made clear in the diagram (Fig. 2) where graphs of the moving averages * of successive 28-days' rainfalls are displayed.

Scrutiny of these graphs shows that each soil begins definitely to dry out when the previous 28-days' average rainfall falls below about 4 ins., and to become wetted again when it rises above about 2 ins. These specific monthly rainfall values agree closely with the critical values tentatively accepted by the writer for the rainfall of the West Indies based on Dr. E. J. Mohr's findings in Java.† According to those findings, a dry month may be regarded as one in which the rainfall is less than 2.4 ins., and a wet month one in which it is greater than 4.0 ins. In the case of sandy and clayey soils at Caroni Estate, the lower limit for rainy months does indeed seem to be roughly 4.0 ins., because both soils begin to dry out when the monthly rainfall is less than this amount, whilst the upper limit for dry months appears to lie near 2.4 ins., since, with monthly rainfalls above this amount falling after a dry spell, the soils begin to acquire moisture again. In dry months, evaporation equals or exceeds rainfall, so that no deep penetration of water can occur. In wet months, not only does much water penetrate deeply where the soil surface is suitably infilterable and the deeper layers fully permeable, but a considerable amount may occasionally run off the land.

(V) Percolation of Water

Attempts were made to measure and to compare the rates of percolation of water through sandy and clayey soils both in the laboratory and in the field. In the laboratory, two aspects were studied, namely (1) percolation through pulverised and sifted dry soil packed uniformly into metal tubes, 1 7/8 ins. wide and 12 ins. long, and (2) percolation through undisturbed soil contained in shallow copper cylinders of depth 2 ins. and diameter 5 ins. (Coile sampling rings), collected by driving the cylinders into the shallow surface soil *in situ*. In the field, percolation was measured by allowing water to run from a calibrated carboy into cylinders, diameter 9 ins. and length 18 ins., driven into the soil when in a suitably moist condition to permit penetration without shattering. The following notes refer to the different methods:—

(1) *Soil packed into tubes*: The sizes of the aggregates and particles obtained by sifting the dry soil samples were 2.0 to 1.0 mm. The ends of the tubes were covered with fine wire gauze. Packing was made tight by jarring. Water absorption was allowed to proceed over-night with the tubes standing vertically in cylinders of water. Percolation was measured by collecting the water that ran down the tube held vertically from a supply contained in a carboy providing a fixed head of water. Graduated cylinders were used to collect the percolates over consecutive time intervals.

* The daily rainfall data used in constructing these graphs were first corrected for "torrential" or "run-off" water, arbitrarily accepted as having intensity above 0.75 inches per hour.

† *The Evaluation of Soil Moisture*, F. Hardy, *This Journal*, 1946. 23, pp. 66–75.

Determinations of percolation rates were made on sandy soil from Field F 72 and on clayey soil from Field F 116 procured in each case at three depths, 0—3, 3—6, and 6—12 ins. These soils closely resemble the sandy and clayey soils occurring in Field F 88. The observed values for volumes collected over successive unit time intervals were graphed. The graphs showed a slight falling off in percolation rate with time but there was always a period when the rate was steady. Values for the percolation constant were taken from observations made within this steady period. They are recorded in Table IV in which the unit of percolation is one cubic centimetre of water that passes *per hour* through a column of soil, one sq. cm. sectional area and depth 1 cm., under a 1 cm. head of water.

TABLE IV

SOIL PERCOLATION CONSTANTS

Soil	Sampling depth	Mean rate of percolation (cc. min.) per tube or cylinder	Percolation constant (cc. hour, 1 sq. cm. 1 cm. dpth. 1 cm. head)	Condition of soil
METHOD 1 (Soil packed in tubes)				
Field F 72 (Sand)	0-3 ins.	0.53	1.75	Saturated and fully swollen after close packing when dry
	3-6 ins.	0.26	0.86	
	6-12 ins.	0.16	0.53	
Field F 116 (Clay)	0-6 ins.	0.155	0.51	
	3-6 ins.	0.049	0.16	
	6-12 ins.	0.019	0.07	
METHOD 2 (Coile's ring)				
Field F 88 (Sand)	0-2 ins.	64	20.2	Saturated in laboratory with natural structure when moist
Field F 72 (Sand)	0-2 ins.	48	15.2	
Field F 88 (Clay)	0-2 ins.	70	22.1	
Field F 85 (Clay)	0-2 ins.	162	51.3	
METHOD 3 (Field cylinder)				
Field F 88 (Sand)	0-18 ins.	223	32.6	Dry soil, natural field structure, finely cracked, wetted during percolation
Field F 72 (Sand)	0-18 ins.	233	34.1	
Field F 88 (Clay)	0-18 ins.	1,640	240.1	
Field F 85 (Clay)	0-18 ins.	730	106.9	

Discussion: The numerical values obtained for the percolation constant for dry soils packed in tubes in the laboratory have very small magnitude.

This may be explained by the initial tightness of the packing and the swelling that occurred as the soils absorbed water in the preliminary wetting, thus greatly diminishing the dimensions of the interstices between the aggregates or particles. The values of the constant for the sandy soils are considerably larger than those for the clayey soils taken at corresponding depths, and they diminish regularly in each case with depth, probably because of diminishing contents of organic matter which confers stability on soil structure. The sandy soil is 3 to 8 times as permeable as the clayey soil for different depths under the conditions of this experiment. Water moves extremely slowly through the clay soil whose swelling must have almost completely sealed up the tubes.

(2) *Soil collected undisturbed in shallow cylinders*: The samples obtained by Coile's method were placed in troughs of water in the laboratory and allowed to become fully saturated by wetting from below. They were then fixed in large Buchner funnels and covered with water having a constant head so that percolation could take place through the natural channels and interstices of the wet soil. The percolates were collected over consecutive time intervals in graduated cylinders as before.

Determinations were made in this way on a large number of replicate 2 ins. samples of sandy soils taken from Fields F 88 and F 72, and of clayey soils taken from Fields F 88 and F 85. The mean results obtained are given in Table IV in which the percolation constant is expressed in the same unit as that used for the first method. The samples were collected during September and October, 1944, when the fields were drying out somewhat.

Discussion: The magnitudes of the values for the percolation constant obtained by this method are 9 to 11 times as large for sandy soils and 45 to 100 times as large for clayey soils as those obtained by the first laboratory method. This can only be explained by the fact that the ring samples were obtained in the field when the soil was neither too wet nor too dry and possessed a well-defined natural

open structure. It should be especially noted that, with the second method, values for clayey soils are larger than those for sandy soils, a rather unexpected result which may be explained by the fact that the percolation rate is decided, not by total pore-space, but by the actual size or cross-sectional area of the interstices between aggregates or particles. In a well-aggregated clay soil, the average size of the interstices may be much larger than those in a sandy soil. It thus appears that the clayey soils possessed a good natural crumb structure or that the small angular units into which the soils cracked when they dried constitute aggregates behaving like crumbs. That these aggregates were fairly stable is indicated by the steady percolation rates which the clayey soil samples showed throughout the experimental runs, although the average time of a run was usually only 15 to 25 minutes.

The sandy soil from Field F88 showed some unsteadiness in percolation rate as compared with the uniform values given by the clayey soil in that the amount of percolation diminished with time. This may be explained by the breakdown of the unstable structure which some sandy soils acquire, or by the gradual silting-up of the pore-spaces.

(3) *Soil in the field* : The wide (9 ins.) cylinders were carefully sunk into the ground so as not to disturb the soil appreciably. The field experiments were performed mostly in October, 1944, during drying weather. The soil at that time was only about one-half saturated with water so that it could be regarded as being relatively dry. In the clay fields, spots were chosen where there were no wide cracks. The percolation rate as measured at these clay sites was steady over relatively long periods, the slowing down being only very gradual. The sandy soils were able to take as much water as the clayey soils at first but the percolation rate fell markedly later, indicating either that their structure was unstable and rapidly broke down on wetting, or that considerable silting-up occurred.

The numerical results obtained are also given in Table IV. * With the exception of the F 88 clay soil, the magnitude of the percolation constant measured in the field is about 1½ to 2 times as large as that measured in the laboratory on undisturbed samples. This may be explained by the occurrence of cracks in the field soil. It should again be noted that values for the clayey soils are numerically greater than those for sandy soils, being about 3 to 8 times as large. This difference may be explained, as in the case of the undisturbed ring samples, by the larger cross-sectional area of the interstices and cracks of the aggregate-structured clay soils.

The rapid diminution in percolation rate observed in the two sandy soils renders the precise measurement of their percolation constants somewhat difficult. This feature of the sandy soils stands out in great contrast to the behaviour of the clayey soils under water percolation in which steady rates are maintained even under a considerable head of pressure. The striking difference between the sandy and the clayey soils is clearly revealed by plotting percolation rate against time. This has been done for values obtained with clayey and sandy soils in Field F 88 (Table V).

TABLE V

DIMINUTION IN FIELD PERCOLATION RATE FOR CLAYEY AND SANDY SOILS

(Percolation rates in hundreds of ccs. per minute per cylinder)

Time (mins.)	2	4	6	8	10	12	14	16	20
Field F 88 : CLAY	21.9	18.4	16.6	16.4	16.4	16.4	16.4	16.4	16.4
SAND	13.2	9.3	6.9	5.3	4.4	3.7	3.2	2.8	2.4

The percolation rate for the clayey soil became steady in about 7 minutes whereas that of the sandy soil was not steady even after 20 minutes and the final value was very much less than the early values.

(VI) Observations on Soil Cracking

Although soil cracking is a common phenomenon, very little information has been published on the subject. It is generally realised that cracking of the soil is beneficial to drainage and soil aeration and is thus an important factor controlling productivity. At Rothamsted, * it has been found that "drainage "takes place mainly through root-holes, worm-holes "and fissures in the soil." In Egypt, † the large cracks that appear during summer fallow periods provide channels which allow deleterious salts to be washed away well beyond the reach of plant roots. These cracks vary in depth from ¼ to 1 metre and their superficial dimensions may exceed 35 per cent.

* Drainage and Evaporation from Fallow Soil at Rothamsted. H. L. Penman and R. G. Schofield, *Journ. Agric. Sci.*, 1941, 31, pp. 74-109.

* The percolation constant for soil in the field is a practical constant that expresses the linear rate at which water will sink through an area of soil just covered with water. Thus for the sandy soil in Field F 88 at the time the experiment was performed, the rate of downward water penetration was about 13 inches an hour and for the clayey soil, about 94 inches an hour, which are very rapid rates indeed. (Green and Ampt., *J. Ag. Sci.*, 1911, 4. pp. 1-24).

† Rôle des Crevasses du Sol. V. M. Mosseri and C. A. Bey. *Sultanic Agric. Soc. Bul.* No. 11, 1923, pp. 11.

of the total surface area. In India,** the most productive fields of black cotton soil were found to contain the largest number of small cracks of size less than 1 inch.

In Frederick Section of Caroni Estate, sandy soils show only very few surface cracks and these are far apart. By contrast, clayey soils are profusely cracked during dry weather. The following notes are based on observations made during numerous field visits in 1944–45 :—

Kinds of cracks: The cracks noted in the Caroni clay fields could be classified into three groups, thus :—

Group i: *Superficial cracks* having depth less than 1 inch and width up to ¼ inch. These appear immediately after dry spells set in.

Group ii: *Intermediate cracks* having depth up to 12 ins. and width between ¼ and 1 inch. These develop during dry intervals between rainy spells.

Group iii: *Deep cracks* penetrating below 12 inches and having width between 1 and 3 inches at the surface. These occur in large numbers during the dry season. Some attain depths of over 36 inches.

Crack area: Measurements were made within a quadrat of area 10 ft. by 10 ft. pegged out in a clay field during dry weather. The area was mapped on graph-paper to scale in 12-inch squares. The widths of the cracks varied up to 3 inches. The total surface sectional area of the cracks was found in this way to be 22 per cent. of the whole area.

Crack volume: A steel frame of dimensions 12 by 12 by 4½ ins. was driven into the soil surface in a clay field in the dry season and the enclosed soil was picked out in layers by hand with the help of a trowel. The volume of the excavated soil was determined in the laboratory by an oil-displacement method and thus the relative volume of crack-space was determined. A second set of samples was taken and treated in the same way. The results obtained for crack-space volume were 32 and 34 per cent. for the top 4½ ins. of layer of soil. For comparison, the experiment was repeated in a sandy soil field. The results obtained were higher, namely, 43 per cent. for duplicate sets of samples, but in this case, the voids mainly comprised interstitial spaces between loose sand particles rather than distinct cracks. The mean value for clay soil agrees with that obtained for crack area, since both give a coefficient of linear shrinkage of 11 per cent. Evidently, however, the sand has a linear coefficient of about 14 or superficial coefficient of 28 which implies that the sectional area of the insterstices of the dry sand is about 27 per cent greater than that of the dry clay.

Crack configuration: Soil cracks usually show a fairly regular polygonal pattern which tends towards hexagonal for well-known geometrical reasons. The pattern is really composite ; the large cracks of Group iii form a large-scale pattern which may involve more than one cane-bed with the separating drains. Inside this, the smaller cracks of Group ii form their own pattern on a similar scale, and similarly for the smallest cracks of all. The relative degree of development of superimposed crack-systems varies greatly with soil-type. Thus, calcareous clay soils (such as the Princes Town Heavy Clay Rendzina comprising the highly-productive black soils of the Naparima District in South Trinidad) tend to develop a small-crack system in which the surface breaks up into numerous, uniform, tiny angular aggregates during dry weather. On the other hand, non-calcareous, highly acid clay soils (such as the Cunupia and Bejucal Clays of the Caroni Plain) tend to develop a larger crack system in which the land surface is broadly dissected though the surface of the individual areas may be so finely cracked as to be powdery.

In profile, horizontal cracks develop conspicuously in the Caroni clays, cutting the soil up into blocks or large angular clods which render digging by means of an agricultural fork relatively easy, the clods being readily prised out in succession like the blocks of a pavement.

Crack formation: Soil-cracks result from shrinkage caused by loss of water from colloidal components or clay minerals of heavy soils. The stresses and strains that are set up within the clay-mass vary greatly in magnitude and tensional direction dependent on the content of colloidal clay and its physico-chemical nature, as well as on the content of organic matter and its degree of humification, and the occurrence of salts. Stresses and strains also depend on the rate of drying out and this in turn depends on the readiness with which the soil cracks. Because these different factors controlling cracking vary markedly from spot to spot, as well as in depth, the parting tension must also vary greatly so that the formation of cracks is very irregular over the field surface.

Sealing up of cracks: During the rainy season, many of the cracks disappear but the manner of closure differs for the different kinds of cracks, as follows :—

Group i: These small cracks close up mainly through the action of beating rain and the running together of the wetted soil particles.

Group ii: These close up in the upper 6 to 9 ins. chiefly through the plugging effect of pieces of burnt trash and cane-ash that have either fallen into the cracks or have been washed in by rain or blown in by wind. Soil-crumb may also fall into the cracks after being sloughed off from the upper sides of the cracks or dislodged from the edges and washed in by rain. Swelling of the plug when wetted may eventually cause compression and complete closure.

** Function of Soil Cracks. A. Screenivasan, *Nature*, 1942, p. 409.

Group iii: These take longest to close up in the rainy season. As in the last group, closure of the upper parts (say down to a depth of 4 inches) may occur through plugging by trash and soil-crumb. The plugs are loose and open at first so that rain-water readily runs through them and is rapidly drained away by the deep, wide, open fissures below. Not all the cracks are superficially sealed in this way; many remain at least partly open throughout the wettest weather. Sooner or later, the deep cracks begin to close from below and small temporary reservoirs of water may collect in them. Water trickles out of these reservoirs when deep drains or pits are dug. The wetting of the clods of soil enclosed by contiguous cracks is generally slow but its rate depends on their size and the nature of their surfaces. These in turn vary in different soil-types. In some cases, the clods are small, soft, friable and porous; in others they are large, hard, glazed and horny in consistency. Such variations may express differences in sand, humus and salt contents, or in chemical composition, lime status, and so on. The more friable clods usually contain soft rusty concretions, spots or pockets of powdery iron oxide, deposited within the zone of intermittent saturation. Cohesion between clods is often prevented or weakened by superficial smears of iron oxide that develop under the oxidising conditions occurring over their surfaces. Cracks which are sealed above by plugs of soil and trash may remain open and dry below and so provide ventilation to the subsoil. The seal prevents water from penetrating, so that the moisture content of the deeper soil may remain at a low level despite wet weather.

(VII) Function of Soil-Cracks

(1) *As drains*: Cracks not only allow clay soils to dry out rapidly to considerable depth in dry weather but they provide a ready means of entry for water when the rains come. If the sealing-up process following wetting is tardy and incomplete, drainage may always be free and the soil may never become saturated, nor will it ever suffer lack of aeration. This state of affairs frequently obtained during periods of light rainfall as revealed by the data accumulated by the investigations described in previous sections.

(2) *As avenues of weathering*: Because of the possibility of extreme aeration in clay soils which crack deeply, progressive oxidation of soil minerals and humic plant residues may go on during dry periods. If sufficient time is allowed, profound weathering of the soil may result until the whole appearance of the profile and many of the properties of the clay are completely altered. Thus, blue-coloured ferrous minerals are slowly converted into yellow or orange hydrous ferric compounds that are gradually irreversibly dehydrated into brown or red residual products. Plant residues containing organic acids may be oxidised to neutral products and thus the degree of acidity may be somewhat lessened. These changes may be very beneficial.

(3) *As agents of self-mulching*: The alternate opening and closing of cracks causes humic material to become incorporated in the lower layers by being blown into the crack openings and falling down into the crevasses. The effect is of small account in any one year but it is cumulative, so that, over prolonged periods, it may gradually improve the physical condition of the soil.

(4) *As aids to tillage*: Observations show that many large cracks of Group iii open and close along the same axes during successive cycles of drying and wetting. Thus when a clay cane-field is ploughed during dry weather after an interval of several years in which a plant-cane and several ratoon crops have been grown, the previous development of a system of regularly-disposed planes of weakness will greatly aid the breaking up of the land and the inversion of the clods. Subsequently, when the field is re-ploughed or harrowed, the additional development of minute crack-systems within and over the surfaces of the clods will greatly aid the further comminution of the larger lumps and so favour the production of tilth.

(5) *As root channels*: But for soil-cracks, the deep penetration by plant-roots would be mechanically impossible in clay soils. The size of an average root-tip has been found to range between 0.50 and 0.10 mm. (about 1/50 to 1/250 ins.) which is much larger than the linear dimensions of the spaces between clay particles or of the micro-pores of soil colloids. Observations in the field show that the finer "feeding roots" of the sugar-cane plant in the Caroni clay soils mainly ramify within the smaller cracks belonging to Group i, having width between 1/8 and ¼ inch. They thus tend to form a superficial system mostly confined to the shallow surface layer of depth one to three inches. Some penetrate further *via* the deeper and wider cracks of Group ii, which go down to 12 inches. The deeper roots grow against the sides of these cracks where moisture is relatively abundant. Since some of these larger cracks close slowly because of swelling when water runs through them, the deeper roots may be flattened and possibly sometimes injured. Many roots of the thicker "anchor" type grow downwards to relatively great depth *via* the largest cracks (Group iii). Many such have been seen at depths between 36 and 72 inches in profile pits; Charter has traced thick sugar-cane roots in the Frederick Series to 100 ins. depth, and has noted "fine root proliferation in the black organic layers," presumably mainly within the top 9 to 12 inches of soil.

Root-hairs given off by the cane-roots enwrap the crumbs or angular fragments formed by the Group i cracks, but they lie flat against the glazed surfaces of the larger cracks or penetrate into secondary cracks that may develop laterally from them.

Summary

1. This paper presents and discusses field and laboratory data obtained during investigations of the moisture and air relations of sandy and clayey sugar-cane soils occurring in Field F 88, Frederick, Caroni Estate, North Trinidad.

2. Moisture and air profile studies were carried out at 4-month intervals during 1943–45 (Table 1 : Fig. 1) ; they demonstrated that, during wet weather, both soils were inadequately aerated because of drainage impedence. During dry weather, the sandy soil was excessively aerated though not necessarily deficient in available moisture. Aeration in the clayey soil was even more excessive in dry weather because of the development of deep cracks, and available moisture was then very deficient.

3. These findings were fully substantiated by a reconsideration of soil moisture data for the top and second foot layers of sandy and clayey soil that had previously been determined weekly during 1927 and 1928 at the same sites. These two years represented an exceptionally wet year and a very dry year, respectively, so that the extreme responses of the contrasted soils to variable weather could be gauged from the data.

4. The results (Fig. 2) proved that both soils were very inadequately aerated throughout the wet year, 1927. The clay soil was almost continuously waterlogged but the sandy soil was much better aerated in the top foot but not so well areated in the second foot layer during the dry season of that year. During the wet seasen of 1927, aeration was fairly good in the second foot layer of the sandy soil. Both soils were excessively aerated during the dry season of 1928, a very dry year, and part of the wet season also, particularly the clay soil because of deep cracking.

5. The results (Fig. 2) also proved that both soils contained about the same abundant supply of available moisture throughout the wet year, 1927, but the cane-plants were probably unable fully to utilise it because of root asphyxiation induced by poor aeration. Both soils were deficient in available moisture during the very dry season of 1928 but not in the wet season of that year. Of the two soils, the clay contained much less available moisture, even in the second foot layer, during the dry season of 1928, again because of deep cracking, conducive to rapid drying.

6. Measurements of infiltration rate were made in the laboratory on sandy and clayey soil-samples collected in shallow cylinders without disturbing the soil structure. It was found that infiltration was more rapid in the clay than in the sand, even though the soils were saturated and covered with a layer of water throughout the trials. Evidently the clay structure is somewhat porous. Smearing the wet clay soil with the finger reduced infiltration to zero.

7. Measurements of percolation rate were made in the field under slightly dry conditions on the two kinds of soils into which wide cylinders 18 ins. long were sunk and a constant head of water maintained. It was found that percolation was many times as rapid in the clay than in the sand ; this result is attributed to deep cracking.

8. Observations made in the field during 1944–45 on soil cracks, cracking and crack-closure are recorded. The functions of cracks are discussed in detail. Although cracks develop only on soil which is freely exposed to intense drying, and are probably most abundant and conspicuous in clay soils deficient in organic matter and devoid of litter, they play a most important part in soil moisture and soil air relations.

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Appendix

SOIL DESCRIPTIONS AND LABORATORY DATA

The following pedological descriptions of the soil-types are taken from Charter's account; the soil names are Chenery's.

		Lower depth (ins.)
(1)	*Washington Clay-Loam* (Field F 84)	
	(i) Grey-brown, friable, vertically-cracking loam with abundant earth worm tunnels.	15
	(ii) Brown, compact, vertically-cracking loam; red-brown-mottled near base.	30
	(iii) Pale brown, dark brown-mottled, compact fine sand.	40
	(iv) Grey-brown and red-mottled compact clay with black manganese peroxide staining. Abundant old cane roots .	117
(2)	*Cunupia Medium Clay* (Field M.P. 11)	
	(i) Grey-brown humic clay or very heavy clay-loam;	12
	(ii) Yellow and brown-grey-mottled clay, speckled black with manganese peroxide;	23
	(iii) Transition; grey-brown orange-mottled, black-stained clay;	27
	(iv) White, grey-brown, ochre-brown or orange-mottled clay, variably speckled and stained with manganese peroxide;	70
	(v) Grey-blue, red-brown-mottled clay. Cane-roots occurred throughout the profile but mostly above 34 ins.	118

PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOILS OF THE OBSERVATION FIELD : CARONI ESTATE : FIELD F 88

Physical Features							Chemical Features					
Lr. dpth. (ins.)	Sand %	Index of texture %	Wilting coeff. wt. %	Satn. capac. Wt. %	Porosity: Capillary Vol. %	Porosity: Non-capillary	Total org. matt. %	Total nitrogen %	C/N ratio	Avail. phos. (Truog) p.p.m.	Avail. potash (exch.) p.p.m.	Reaction pH
(1) SANDY SOIL ("Good" Plot)												
3	52	18	11	35	25	22	2.5	.17	8.9	935	45	7.1
6	52	18	11	32	24	21	2.4	.15	9.0	392		7.1
9	50	18	11	31	24	17	1.7	.13	7.8	124		7.0
12	50	18	11	30	26	17	1.7	.13	7.7	100		7.0
18	53	17	10	29	25	18	1.4	.11	7.1	77		7.3
24	50	18	11	30	26	17	1.0	.10	6.0	29		7.5
(2) CLAYEY SOIL ("Bad" Plot)												
3	22	33	20	40	44	9	3.1	.23	7.9	86		6.8
6	20	34	20	39	44	7	2.6	.21	7.3	95	105	7.0
9	17	34	20	37	45	5	2.2	.20	6.5	87		7.1
12	13	33	20	38	44	7	1.6	.16	5.8	81		7.2
18	11	36	22	37	49	1	1.0	.14	4.2	80		6.6
24	5	37	22	37	49	1	0.8	.12	3.7	113		5.6

Chemical features : Soil reaction is neutral to markedly alkaline. Alkaline reactions may be attributed to liming whose effects seem to have penetrated deeply in the sandy soil but only the depth of the ploughed layer (12 ins.) in the clay. Organic matter and nitrogen contents are medium-low with very low C/N ratio, indicating long-continued erosion and wastage of the original upper organic soil layer.

Some mixing of upper soil has gone on, presumably a result of ploughing. Available phosphate content is exceptionally high in the sand and medium-high in the clay. The field is adjacent to an estate railway line so that it may have recently been given heavy dressings of filter-press cake rich in calcium phosphate. Available potash content is very low in the sand and low in the clay.

NOTE : These two soil profiles exhibit features caused by disturbance brought about by long-continued cultivation and surface erosion. The "soil-types" which they represent (as well as others occupying the Caroni Plain) are evidently merely cultivation-erosion phases of natural Intrazonal-Hydromorphic soils of which entire or complete examples no longer occur anywhere within the region. Removal of the original surface litter and much of the organic soil and thorough mixing of the uppermost part of the profile have tended in each case to produce a fairly uniform surface layer down to a depth of about 18 ins. in the sand and 12 ins. in the clay. Liming has also altered the reaction relationships, and treatment with filter-press mud has profoundly affected the phosphate status, of the upper part of the clay profile.

EXPLANATION OF FIGURE 1

The main results obtained in the (first) investigation on the changing moisture and air profiles of sandy and clayey soils are depicted in the block diagrams.

(A) DESCRIPTION

Each diagram shows the porosity characteristics of the contrasted soils.

(i) The thick horizontally-shaded area on the left represents the percentage volume of *dry soil matter*.

(ii) The cross-hatched area on the right represents the percentage volume of the *capillary pore-space*, that is, pores which can store water but are too small to store air since they belong mostly to colloidal matter.

(iii) The unshaded area represents the percentage volume of the *non-capillary pore-space*, that is, pores through which water can pass readily under the action of gravity and which can store air and permit ventilation.

(iv) The blackened area represents *soil organic matter*.

(v) The dotted area represents the percentage volume occupied by *water* at the time of sampling.

(vi) The thin vertical white line through the water content of the capillary pore-space divides unavailable water (below wilting point) from *available* water (on the left).

(vii) The percentage volume of the free *air-space* at the time of sampling is represented by the difference between the total porosity and the volume of water. Where it encroaches on the capillary pore-space, it is assumed that cracks have developed.

(B) DEDUCTIONS

(1) *Sandy soil* :

(i) In the *wet* sandy soil (Nos. 1, 2), all the capillary pore-space and most of the non-capillary pore-space are occupied by water, presumably because of impeded drainage. As the soil dries out (No. 3) the non-capillary pore-space is gradually emptied of water and air takes its place.

(ii) In the *dry* sandy soil, (Nos. 4, 6), some of the water in the capillary pore-space dries out; this is accompanied by shrinkage or collapse, so that slight cracks appear. Available water is quite absent in the top foot (No. 6).

FIGURE 1

SOIL MOISTURE AND SOIL AIR PROFILES

CARONI SUGAR ESTATE
FIELD F88

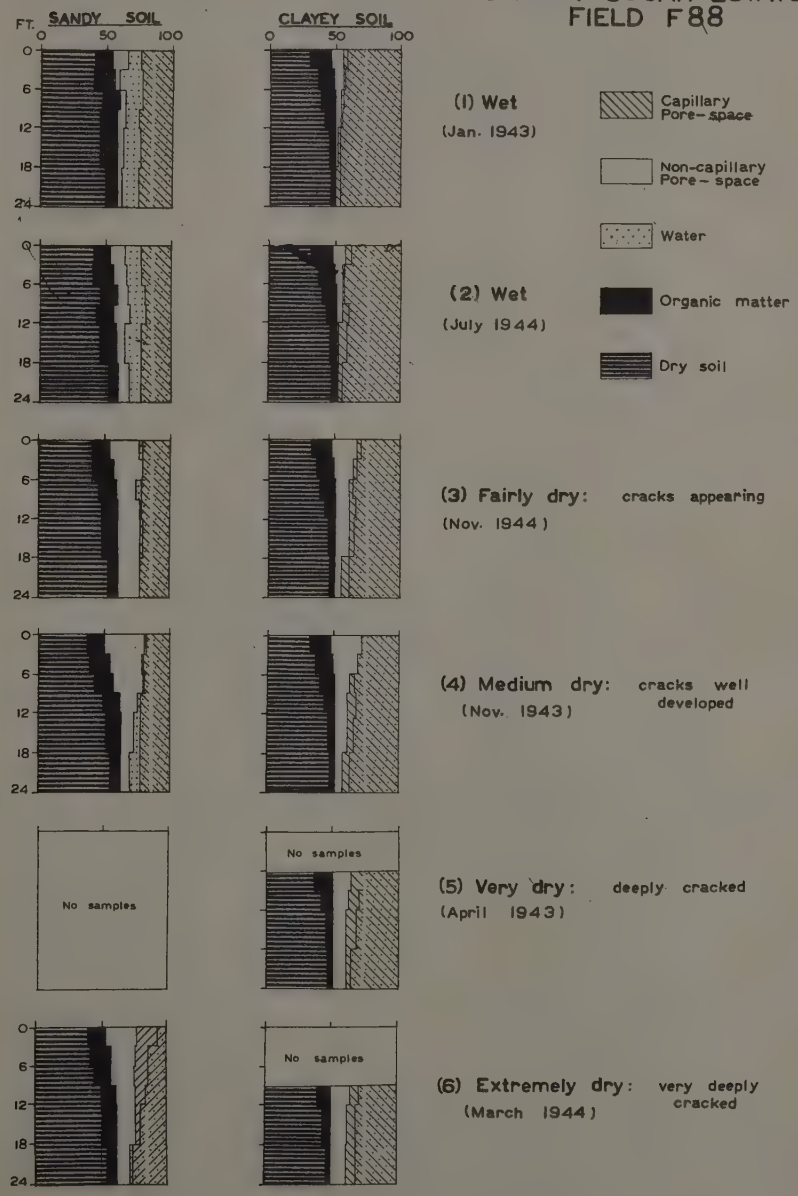
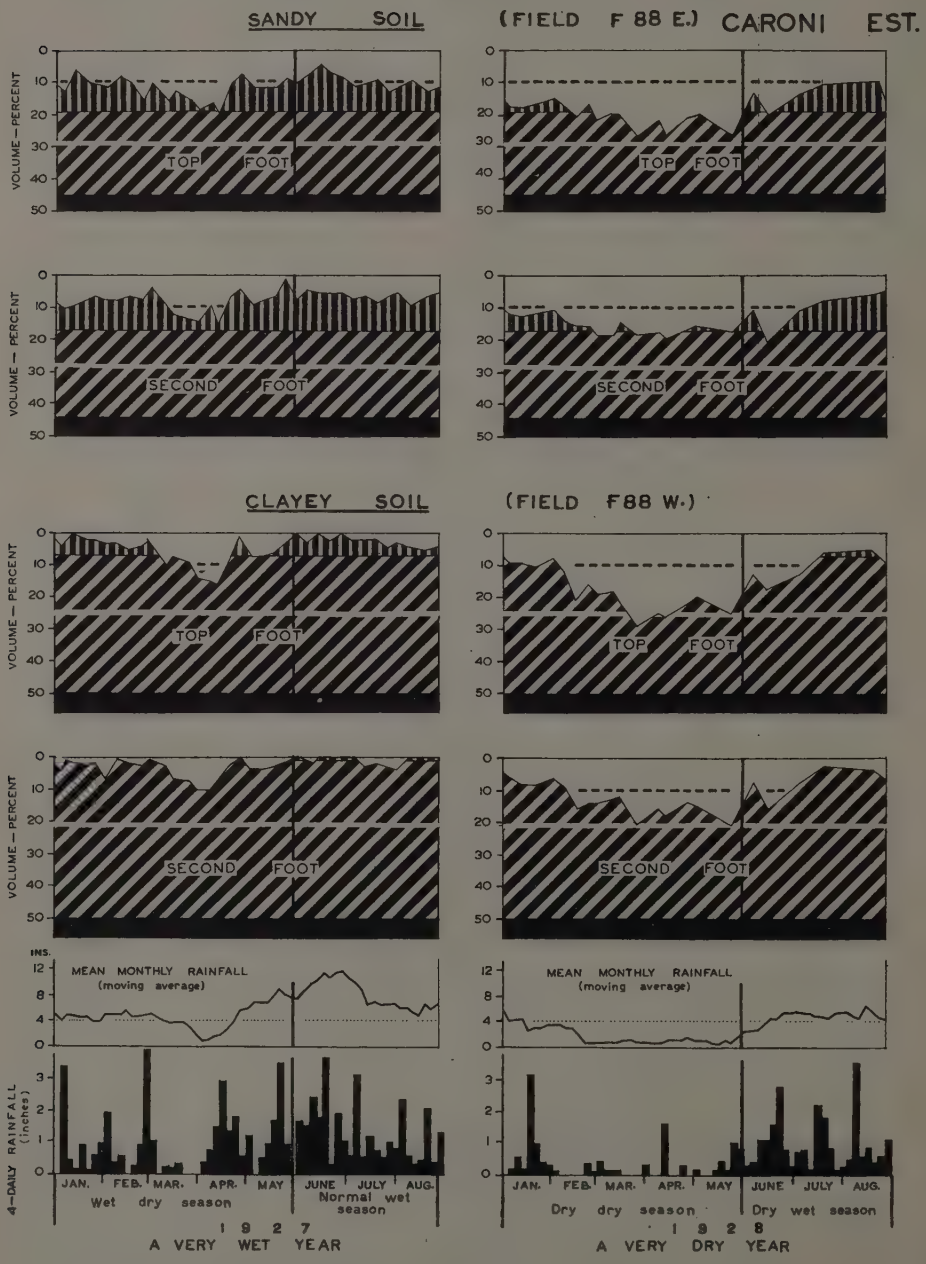


FIGURE 2
FLUCTUATIONS OF MOISTURE AND AIR



(2) *Clayey Soil* :

(i) In the *wet* clayey soil (Nos. 1, 2), nearly all the capillary pore-space, though none of the sparse non-capillary pore-space, is occupied by water. As the soil dries out (No. 3), shrinkage occurs and cracks appear.

(ii) In the *dry* clayey soil (Nos. 4, 5, 6), the cracks widen and deepen. Available water is absent in the upper layers, even at medium-dryness (No. 4).

EXPLANATION OF FIGURE 2

The main results obtained in the (second) investigation on soil moisture and soil air fluctuations in sandy and clayey soils are depicted in the graphs.

(A) DESCRIPTION

Each graph shows the partition of water and air.

(i) The white unshaded upper area bounded by the zig-zag line indicates the volume of free air contained in the pore-spaces of the soil as determined weekly for 5 dry season and 3 wet season months. The change in seasons is shown by a vertical black line.

(ii) The horizontal dotted line at the 10 per cent. level marks the arbitrary lower limit of adequacy for soil aeration.

(iii) The shaded area indicates the corresponding volume of water, non-capillary water being represented by vertical stripes and capillary water (field capacity or index of texture water) by inclined stripes.

(iv) The white horizontal line marks the wilting co-efficient level or the lower limit of available water.

(v) The thick black horizontal stripe at the bottom of the graph represents the beginning of solid-soil volume which, if continued downwards, would make up a total of 100 per cent.

(vi) The black vertical columns ("chimney-stacks") at the bottom of the figure represent 4-daily rainfalls in inches.

(vii) The zigzag line above the rainfall columns gives the monthly (28-day) rainfall, expressed as a 4-day moving average, in inches. The critical value denoting "soaking rains" appears to be 4 ins.; it is indicated by the fine dotted horizontal line.

(B) *DEDUCTIONS*

(1) *Sandy Soil* :

(i) In the *wet year* (1927), aeration was adequate in the top foot but inadequate in the second foot, except for 5 weeks in the dry season.

(ii) In the *dry year* (1928), aeration was excessive in both layers.

(iii) Available water was adequate throughout the wet year but probably deficient in the dry season and in the first month of the wet season.

(2) *Clayey soil* :

(i) In the *wet year* (1927) aeration was inadequate in both layers except for 3 weeks in the dry season. The soil was nearly waterlogged for most of the year.

(ii) In the *dry year* (1928), aeration was excessive in both layers.

(iii) Available water was adequate in the wet season but very deficient in the dry season and the first 6 weeks of the wet season.

TUNG TREE CULTIVATION IN NYASALAND

The two species of trees which produce tung oil, *Aleurites fordii* and *A. montana,* were introduced into Nyasaland in 1927 and 1931 respectively. *A. fordii* has proved to be unsatisfactory, and the superiority of *A. montana* has resulted in its being planted almost exclusively since 1936. Since then the total area under tung trees in the protectorate has increased from 624 to 8,349 acres at the end of 1944. The species is monoecious; 40 to 50% of the trees are very predominantly male and bear only a few clusters of fruit, whilst the remainder ("bearers") produce far more female flowers and so set far more fruit. It follows that the vegetative propagation of the best bearing trees offers great possibilities in improving yield, for males would be eliminated and the plantation would consists of clonal material derived only from the outstandingly good bearers. Selection of good mother trees started in 1940. Budding on to seedling rootstocks was found to be a simple matter and the resulting budded plants were easy to handle and transplant (*H.A.* 11 : 898 : 12 : 1487). 68 clones are now under trial, but less than half are in bearing, and the present paper refers only to the 12 oldest clones planted in 1940. Buddings on *A. montana* stock have significantly outyielded those on seedlings, giving nearly three times as much as those on unselected seedlings. The *A. fordii* stock is exerting a dwarfing effect, and its yield fell below that of the buddings on the *A. montana* stock in the fourth year, and is expected to continue to do so. Seedlings of the candlenut tree (*A. moluccana*) have also been tried as a stock for both *A. montana* and *A. fordii,* but the species appear to be incompatible. Attempts are being made to root clonal material as cuttings. In the older seedling plantations the topworking of the male trees by budding on to the main branches with scion buds from high-yielding mother trees has been found to be a successful means of converting these trees into good bearers. Cultural methods are discussed under nursery work, transplanting, spacing, cultivation, manuring and pollination. No definite conclusions can yet be drawn from an intercropping trial, but results so far show a consistent superiority of the soya-beans plots both as regards yield and vigour, thus indicating the advantage of thorough cultivation with a crop which does not take much from the soil. To ensure adequate pollination a small proportion of early flowering male trees in a budded plantation is desirable, and at present not less than 5% of males is suggested. (*Horticultural Abstracts,* 17, 205, 1947 : Review of paper by C. C. Webster in *Emp. J. Exp. Agri.* 14, 1946.)

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EXPERIMENTS IN THE DRYING OF DERRIS AND LONCHOCARPUS ROOTS

BY

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Introduction

The roots of *Deris* and of *Lonchocarpus* species are valued for their insecticidal properties, which are partly due to the presence of rotenone. The fresh root contains about two-thirds water and must be dried before the product is ground for use as an insecticide. The expressed juice of the root is a valuable insecticide but no practical process has been devised for the commercial preparation of rotenone products from the juice.

While the roots are drying, three separate processes occur: (1) Evaporation of water, (2) degradation of rotenone and related compounds by air and light, and (3) the loss of dry matter other than rotenone. It is known that the rotenone in dry derris root is quite stable so that over a period of several years there is no appreciable loss of toxic properties if the dry powder is stored away from heat and direct sunlight. It has also been demonstrated [1] that finely divided rotenone preparations sprayed on a plant lose their insecticidal value after 5 to 10 days as a result of photochemical decomposition by sunlight. It, therefore, becomes a problem of economic importance to determine whether drying the root in the sun causes loss of rotenone.

It has been stated, without experimental data, that rotenone-containing roots should be dried in the shade. This, of course, is more time-consuming and requires the necessary shaded areas. This recommendation is probably based on the known photodecomposition of the insecticidal preparation. It may also have been the result of the observations that shade-dried roots are generally somewhat darker than those sun-dried, and high-rotenone roots, no matter how dried, are darker than low-rotenone roots. These two facts may have given rise to the conclusion that shade-drying is preferable.

It is the purpose of this paper to present the experimenal work on drying carried out at this station. Experiments were made to compare sun and shade-drying and also to determine the effect of very slow drying to see whether the cured product would be superior or inferior to rapidly dried material.

Materials and Methods

The roots used in this work were from *Derris elliptica* (Wall.) Benth. variety Sarawak Creeping and *Lonchocarpus utilis* A. C. Smith. The samples consisted of roots taken from numerous plants from 2 to 7 years old.

In preliminary work it was found that representative samples of reasonably small size could not be obtained from whole root. When duplicate 500-gram samples of whole root were selected, the rotenone content varied several per cent. so that changes during drying could not be definitely ascribed to the drying method used. Rather than use larger samples or numerous replicates, it was decided to cut the roots into short pieces. By this means the weight of the sample could be reasonably small and the number of pieces sufficiently large so that analyses of duplicate samples would differ in rotenone content only in the tenths of per cent. Cutting would also serve to exaggerate any effect due to light or air.

For each experiment several kilos of root were harvested, washed immediately and allowed to drain while being cut into 2 to 2.5 cm. pieces. Since fine roots and thick roots are low in rotenone [2], these sizes were discarded in order to obtain samples that were as homogeneous as possible. The pieces used were from 3 to 10 mm. in diameter. After cutting, the entire lot was thoroughly mixed by pouring from one container to another. Samples were then weighed into tared containers for the different treatments to be used. This procedure was carried out with despatch in order to decrease drying prior to experimental treatment.

In each test several representative samples of fresh roots were taken as controls to determine the initial moisture, total chloroform extractives, rotenone and rotenoid content of the roots. These data were used for calculating the losses of the various constituents in the treated samples.

To determine the moisture content of the fresh root, as well as of the treated material, weighed samples were dried in an oven at 105° C. for 2 hours. After cooling in a desiccator over $CaCl_2$ for an hour, weights were taken and the heating and cooling repeated until minimum, constant weights were obtained. The loss in weight during drying multiplied by 100 and divided by the original weight was regarded as the moisture percentage on the assumption that the loss of volatile matter other than water was negligible.

For the other determinations on the controls and on the treated lots, the samples were dried at 80° in an oven for one-half hour and then at 50° for 4-hour periods alternated with cooling in a dessicator over $CaCl_2$ until constant weights were

1. Chisholm, Robert D. Derris stability.....Effect of temperature and light upon the decomposition of derris. *Soap* (Sanit. Prod. Sect.) 15 (5): 103, 105. 1939. (See references given therein.)

2. Puerto Rico (Mayaguez) Agricultural Experiment Station. Investigations of Insecticidal Crops. Physiological Studies. *Puerto Rico (Mayaguez) Agr. Expt. Sta. Rpt.* 1939: 75. 1940.

attained. Since the pieces were then not entirely dry, moisture determinations were made on small sub-samples cut from numerous pieces in the main sample. The remainder of the sample was then ground in a Wiley mill through a 1 mm. sieve and a ½mm. sieve, the powder thoroughly mixed and spread in a 1-inch layer on a paper. One half was removed and the remainder mixed again and spread. This was repeated until about 100 gm. remained which constituted the sample for chemical analysis.

The rotenone content was determined by the ADOAC method[3] and the total chloroform extractives were determined from an aliquot of the chloroform extract prepared for rotenone analysis. This aliquot was evaporated to dryness on a water bath and dried in an oven at 105° for half-hour periods alternated with cooling in a desiccator over $CaCl_2$ until constant weight was attained. The rotenone-plus-rotenoids content was determined by a colorimetric procedure[4] based on the development of a red colour in a rotenone solution treated with KOH, $NaNO_2$, and then with dilute H_2 So_4.

From these data the amount of dry matter, total chloroform extractives, rotenone-plus-rotenoids, and rotenone were calculated for each sample before and after treatment.

Experimental

Sun versus Shade-drying

Experiment 1. The first experiment involved a direct comparison between derris root dried in the sun, in the shade, and in the oven. On the fifth day the samples in the sun were at minimum weight. Those in the shade required 7 days. The oven-dried material was kept at 80° for a half-hour and then at 50° for 16 hours to attain a constant weight. Duplicate analyses of duplicate samples gave the following percentages of rotenone: Sun 7.99; shade 7.97; and oven 7.65. Since the differences were relatively small there was no appreciable effect of drying method on rotenone content.

Experiment 2. In this experiment the following treatments were used with duplicate 200-gram samples of derris root; (1) Control, oven-dried as above, (2) dried in a vacuum oven over $CaCl_2$, (3) whole pieces, sun-dried, (4) whole pieces, shade-dried, (5) pieces split to 2 mm. lathes, sun-dried, and (6) pieces split as in (5), shade-dried. The splitting was expected to exaggerate any change brought about by an increase of the exposed surface. Sun-drying of split pieces was completed in 2 days while 5 days were required for the whole pieces. The split pieces were exposed to the sun for an additional 5 days to allow for the same time of exposure. Shade-drying was completed in 4 days for the split pieces and 15 days for the whole pieces. The results presented in Tables 1 and 2 showed no losses of dry matter, total chloroform extractives, rotenone-plus-rotenoids, or rotenone.

Experiment 3. An experiment similar to the foregoing was made with lonchocarpus root. Sun-drying was completed in 2 days for the split pieces and 4 days for the whole pieces. About 2 weeks were required for the material either whole or split to dry in the shade. The results showed some loss of dry matter as a result of shade-drying. Those roots dried whole in the shade lost 6.8 per cent. of their original dry matter, while the split ones lost 5.5 per cent. However, these losses increased the percentages of extractives and rotenone so that no extractives or rotenone were lost by either sun or shade-drying of whole or split pieces.

Storage Experiments

Several experiments were conducted in which the samples of fresh derris roots were stored under different conditions for various periods of time before drying. The purpose of this work was to simulate

3. Association of Official Agricultural Chemists. Official and Tentative Methods of Analysis.....Ed. 5. 757 pp., illus. Washington, D.C. 1940. (See pp. 64-65.)

4. Jones, Merriam A. Application of a modified red-colour test for rotenone and related compounds to *Derris* and *Lonchocarpus*. *Assoc. Off. Agr. Chem. Jour.* 28: 352-359. 1945.

TABLE 1.—Chemical analyses of *Derris* root before and after drying

Drying treatment	Initial rotenone	Final [1] rotenone	Initial total extractives	Final [1] total extractives	Initial red-color value	Final [1] red-color value.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Whole roots in air oven	6.1	6.1	16.9	16.9	14.9	14.9
Whole roots in vacuum oven ..	6.1	6.4	16.9	17.8	14.9	15.7
Whole roots in sun	6.1	6.1	16.9	17.5	14.9	15.1
Whole roots in shade	6.1	6.6	16.9	18.1	14.9	16.4
Split roots in sun	6.1	6.4	16.9	18.1	14.9	15.8

1. Some of the final values are larger than the initial. This is an apparent increase rather than an actual increase, resulting from a loss of dry matter.

slow drying, such as would be accomplished in large stacks of root being dried in the shade, and to try to determine whether rotenone losses during storage are due to enzymatic action or to decay.

Experiment 1. In the first trial derris root was stored for 1 day and for 14 days in closed vessels over water and over aqueous solutions of ammonia, hydrochloric acid, and ethylene gas in concentrations of 2, 5, and 10 ml., respectively, in 200 ml. of water. These treatments resulted only in small losses of dry matter.

Experiment 2. This experiment was similar to the previous one except that the ammonia treatment was omitted and the storage periods were 1 and 3 months. Losses of dry matter were 8 to 12 per cent. in the material stored 1 month and 19 to 29 per cent. in that stored for 3 months. Among treatments and between duplicate samples of the same treatment, a considerable variation was observed in the amount of mold appearing during storage. In the samples stored for 3 months there were different amounts of apparent hyperlenticular activity and considerable variation in the number of sprouts and adventitious roots on the pieces. Losses in total chloroform extractives during storage for 3 months varied considerably and in some treatments were as great as 37 per cent. of the amount originally present. Likewise, rotenone losses were as high as 17 per cent. in those stored 1 month and 49 per cent. in those stored 3 months.

Experiment 3. In another experiment with derris root the following treatments were used: (1) Stored over water, (2) stored over water (500 ml.) containing bromine (3 drops), (3) steamed 5 minutes over boiling water in a closed vessel at atmospheric pressure followed by storage over water, and (4) steamed as in (3) and stored over bromine water as in (2). Adequate controls, included to determine any effects of the initial treatments, showed that immediate changes in the material were negligible. Mold appeared in all of the stored samples, but no adventitious root development or hyperlenticular activity was apparent. The losses during storage are shown in Table 3.

TABLE 2.—[1] The effect of several drying treatments on the quality of derris root.

Drying treatment.	Initial [2] dry matter	Final [2] dry matter	Loss	Initial [3] rotenone content	Final [4] rotenone content	Initial [3] total extractives	Final [3] total extractives	Initial [3] red color value	Final [4] red color value
			Per cent.						
Whole roots in air oven	64	64	0	4	4	11	11	10	10
Whole roots in vacuum oven ..	64	62	3	4	4	11	11	10	10
Whole roots in sun	64	62	3	4	4	11	11	10	10
Whole roots in shade	64	59	8	4	4	11	11	10	10
Split roots in sun	64	63	1	4	4	11	11	10	10
Split roots in shade	64	61	5	4	4	11	11	10	10

1 Results appearing in this table are the averages of the duplicates calculated to the nearest gram and nearest per cent.
2. Calculated as follows: (100—per cent. moisture) x wt. of roots in grams.
3. Initial per cent. constituent x initial dry matter.
4. Final per cent. constituent x final dry matter.

TABLE 3.—Losses from undried derris root during 3 months' storage under different treatments

Treatment	Losses [1] during storage				
	Moisture	Dry matter	Total chloroform extractives	Rotenone plus rotenoids	Rotenone
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
None	48	36	61	68	72
Bromine	29	22	3	7	3
Steam	37	33	34	41	40
Steam and bromine	23	18	1	2	1

1. Calculated from analysis of fresh roots at initial sampling and after 3 months' storage.

From these data it appeared that all of the treatments reduced the losses of rotenone during storage but bromine treatments were the most effective. Since none of the treatments visibly affected mold, the differences appear to be independent of this condition. It was observed that the colour of the ground roots and of the acetone and chloroform extracts made from them was dark in proportion to the amount of rotenone lost during storage.

Experiment 4. In another trial derris samples were submitted to the following treatments: (1) Control, dried immediately, (2) autoclaved 10 minutes at 120°, dried immediately, (3) stored over water, (4) stored over bromine water (1:500), (5) stored over water in a chamber which was repeatedly deaerated and flushed with carbon dioxide, (6) autoclaved, kept sterile, stored over water, (7) autoclaved, exposed to air, stored over water, and (8) allowed to dry slowly in the laboratory under poor drying conditions. The storage period was 3 months. Although losses of dry matter were as much as 20 per cent., losses of extractives, rotenone-plus-rotenoids, and rotenone were small and erratic.

Experiment 5. At the time of initiation of the foregoing experiment, another set of sixteen 100 gm. samples of derris root were stored, 8 sealed airtight in Mason jars and 8 loosely stoppered but sufficiently closed to minimize moisture losses. To some of the stored samples 1 ml. of toluene was added as a preservative. Duplicate samples from each method of storage were dried for analysis after fixed periods of storage. During 2 weeks' storage it was noted that adventitious roots had formed on many of the pieces kept in loosely stoppered jars except those in the jar to which 1 ml. of toluene was added at the beginning of storage. Mold developed on all the loosely stoppered samples. In the sealed jars some pressure had developed and when this was released a strong acid aroma was noticeable. It was also noted that in the sealed jars a small amount of milky water had accumulated among the pieces and at the bottom of the jar. Roots 5 to 15 mm. in length, had formed on 20 per cent. of the pieces stored in the loosely stoppered jars but only on 2 per cent. of the pieces stored in sealed jars. Analyses showed about 10 per cent. losses of dry matter in both methods of storage but practically no change in the extractives or rotenone.

After 3 weeks' storage the unsealed samples had roots 8 to 30 mm. long on about 30 per cent. of the pieces. One of these samples was divided into two sub-samples: pieces with and pieces without rootlets. In this manner it was found that, although the pieces were in the same jar, the ones with adventitious roots lost 20 per cent. of their original rotenone while those without rootlets lost practically none. The duplicate sample of the one sub-divided was not separated into pieces with and without rootlets; the rotenone loss in this sample was about the same as the total loss in the sample in which the pieces were separated. A considerable amount of mold was present on one of the sealed samples but neither showed any loss of rotenone.

After storage for 5 weeks, samples were taken and the unsealed ones divided into pieces with and without adventitious roots. From 20 to 30 per cent. of the pieces stored unsealed had new roots up to 25 mm. long which had withered considerably during storage. Those with new roots had lost about 30 per cent. of the rotenone as compared to 10 per cent. loss for those without new roots. Those stored sealed lost no rotenone. Many of the pieces were punk-like from decay and some mold was present but neither of these observations seemed to be related to rotenone loss.

After 3 months' storage the last samples were taken. The unsealed sample to which 1 ml. of toluene had been added at the beginning of storage showed no adventitious rooting; about 50 per cent. of the rotenone was lost in this sample during storage. The other unsealed sample was separated into pieces with and without adventitious roots. These showed 66 per cent. rotenone loss while pieces without new roots showed 50 per cent. rotenone loss. The sealed samples, one with toluene and one without, showed only small losses.

Experiment 6. In this storage experiment with derris root, samples were stored, sealed and unsealed, for periods of 0, 2, 4, 8, and 12 weeks. Other samples were treated as follows and stored 12 weeks: (1) sterilised 15 minutes at 120°, (2) treated with 1 ml. of toluene, and (3) stored untreated under a water-seal device so that no appreciable pressure would develop. The results are summarised in Table 4.

Differences in the apparent amount of mold present seemed to have no appreciable effect on the rotenone losses. Only untreated material which was stored unsealed developed adventitious roots. Unsealed pieces lost about half of the original rotenone during 12 weeks' storage. Sterilisation before storage had little effect on the sealed material, but in the unsealed series, it appeared to reduce the rotenone loss. As noted in the previous experiment, rotenone losses were very small in samples stored in sealed jars; also these samples did not become appreciably darker and they developed a fruity acid aroma similar to that of "jobos" (*Spondias mombin* L.) unlike the resinous smell characteristic of fresh derris root. Treatment with toluene did not affect the sealed material but sterilisation appeared to destroy a small amount of the rotenone. In the unsealed series rotenone losses increased with time of storage and were somewhat greater in the pieces with adventitious roots. The sterilised root lost less rotenone during storage than did the unsterilised.

Experiment 7. An experiment similar to the foregoing was carried out with lonchocarpus root. Duplicate samples were stored for 0, 4, and 12 weeks, sealed and unsealed, with and without toluene. The results are summarised in Table 5.

The results were similar to those obtained with derris root. The sealed samples lost little dry matter and rotenone while those unsealed lost more. The pieces with adventitious roots lost more rotenone than those without. The toluene treat-

TABLE 4

THE EFFECT OF SEVERAL STORAGE TREATMENTS ON THE QUALITY OF UNDRIED DERRIS ROOT

Sample	Storage period	With new roots (1)	Losses during storage			Colour and odour
			Dry matter	Total extractives	Rotenone	
	Weeks	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Control	0	0	0	0	0	Light brown
Sealed	2	0	11	0	0	Light brown fruity
Unsealed	2	25	22	6	14	Dark brown
a. Without rootlets			22	7	13	
b. With rootlets			22	5	15	
Sealed	4	0	13	0	0	Light brown, fruity
Unsealed	4	28	29	20	28	Dark brown
a. Without rootlets			29	19	27	
b. With rootlets			29	24	33	
Sealed	8	0	12	0	4	Light brown, fruity
Unsealed	8	21	31	24	32	Black
a. Without rootlets			31	23	30	
b. With rootlets			31	27	37	
Sealed	12	0	14	0	4	Light brown, fruity
Sealed, autoclaved	12	0	1	0	10	Light brown
Sealed, toluene	12	0	9	0	2	Brown
Sealed, water seal	12	0	15	0	7	Light brown, fruity
Unsealed	12	28	37	37	47	Black
a. Without rootlets	—	—	37	34	44	
b. With rootlets	—	—	37	41	53	
Unsealed, autoclaved	12	0	35	15	27	Black
Unsealed, toluene	12	0	35	37	45	Black

(1) Samples containing some pieces with adventitious roots were separated for analysis into pieces with and pieces without such new rootlets. The data for the combined sample were calculated from the sub-samples.

TABLE 5

THE EFFECT OF SEVERAL STORAGE TREATMENTS ON THE COMPOSITION OF LONCHOCARPUS ROOT

Treatment	Storage Period	With Rootlets	Losses During Storage			Colour and odour
			Dry Matter	Total Extractives	Rotenone	
	Weeks	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Control	0	0	0	0	0	Light brown
Sealed	4	0	0	0	0	Light brown, fruity
Unsealed	4	11	23	1	1	Brown
a. Without rootlets	—	—	23	0	0	
b. With rootlets	—	—	23	5	6	
Sealed	12	0	11	0	0	Brown
Sealed, toluene	12	0	13	4	2	Brown
Unsealed	12	0	52	20	23	Decomposed
Unsealed, toluene	12	0	58	47	51	Decomposed

ment was ineffective. The unsealed samples stored for 12 weeks were so badly decomposed that no adventitious roots could be observed.

Conclusions

It is clear from these experiments that derris and lonchocarpus roots should be dried as rapidly as possible to prevent loss of rotenone. Artificial heat may be used but under field conditions sun-drying is more practical. Sun-drying is superior to shade-drying because it is faster. Shade-drying of large amounts of root would require considerable drying area and, if sufficiently slow, would result in loss of rotenone.

Concerning the losses of rotenone that occur during storage of undried root, the following conclusions can be drawn: The presence of mold or punk-like appearance and texture in the stored root is not necessarily accompanied by loss of rotenone. It appears that the factors to which rotenone loss may be ascribed are: (1) The development of adventitious roots. It may be that the rotenone is used up in the formation of new tissue or that those pieces that develop new tissue are more susceptible to oxidative rotenone loss or that those particular pieces contained less rotenone in the first place. (2) The main cause of degradation appears to be due to oxidation, partly enzymatic, that takes place in the moist tissue.

Since derris and lonchocarpus roots are usually harvested during the wet season, it may be that steps would be necessary to keep the roots from being continually wetted by drenching rains. In order to facilitate rapid drying, the roots may be stored on wrie or bamboo shelves. Several tiers of shelves may be constructed, the lower one about 3 inches from the ground with a vertical interval of 3 feet between shelves. The upper shelf could be thatched to keep off the rain and the long axis of the shelves could be in the north-south direction so as to allow for sun exposure from the east and west. The area should be in a valley or a cut where breezes maintain circulation of air. The roots could then be piled on the shelves, whole or cut, and turned at intervals to facilitate drying. Another type of construction that would allow for sun exposure is one used for coffee drying. This consists of a number of shelves about 20 x 50 feet, each of which is mounted on tracks so that the shelves can be arranged in cascade fashion in the sun, and, in case of rain, can be wheeled together, one over the other, under a rainproof roof.

Summary

1. It was shown that sun-drying of derris and lonchocarpus is more practical than shade-drying because the rate of drying is faster in the sun and no degradative changes occur.

2. Slow drying, as simulated by storage of undried root, leads to the loss of rotenone.

3. Two constructions were described for use in the sun-drying of root.

MISCELLANEOUS NOTES

East African Central Veterinary Research Institute

The appointment is announced of Dr. Edwin George White, Ph.D. (Lond.), B.Sc. (Vet. Sc.), B.Sc. (Physiol.) (Lond.), M.R.C.V.S., as the first Director of the East African Central Veterinary Research Institute, Kabete, Kenya Colony.

Shortly before the outbreak of war it had been decided that a central research station should be commenced for the study of veterinary problems in East Africa. Arrangements were in hand to obtain the necessary staff, but the outbreak of war necessitated the postponement of much of the envisaged work and rendered impossible the filling of staff appointments.

The project is now to be renewed and the research will be carried out at the Institute at Kabete which, in the past, has been used for Kenya veterinary research. At this station problems common to all the East African territories will be investigated; the Institute is to serve as the centre for fundamental research in veterinary science in East Africa, covering Kenya, Tanganyika and Uganda. This is in addition to the research work carried out at the various laboratories in the three colonies coming within the administration of the Directors of Veterinary Services. The Institute will also play a part in the training of African veterinarians and in providing research training for European veterinary graduates who join the Colonial Service in East Africa.

Morphological Change Induced in Leaves of Theobroma cacao by Mineral Deficiency

The leaves of the cacao seedlings, which grew in pots and showed severe symptoms of lime-induced chlorosis, were observed to develop a number of sharp dentations at the tip. Thereafter, seedlings were grown in water cultures lacking iron and manganese. These plants produced deeply indentate leaves, while other seedlings raised in water cultures lacking only one of these substances formed normal, entire leaves. This is believed to be the first record of the influence of mineral supply on leaf shape. The significance of the observation for the identification of species is pointed out. Photographs show the normal and indentate cacao leaf.—West African Cacao Research Institute, Tafo, Gold Coast. (*Horticultural Abstracts*, 17, 210, 1947.)

FERTILIZER FIELD EXPERIMENTS WITH SUGAR-CANE ON PHOSPHATE-DEFICIENT SOILS IN SOUTH TRINIDAD

BY

J. A. POTTER

(Field Superintendent, Ste. Madeleine Sugar Company, Ltd., Trinidad)

PART I

Introduction

(1) General : Between 30 and 40 per cent. of the sugar-cane crop of Trinidad is grown in the Naparima District in the south of the Island, and 90 per cent. of this is grown by the Ste. Madeleine Sugar Company, which controls some 24,000 acres of land. Half of the crop is produced on the plantation system on company-operated estates, and half by peasants known locally as "cane farmers".

(2) Soils : Two main sugar-cane soil-types predominate in the Naparima District; they may conveniently be designated *Red Soil* and *Black Soil*. They have been variously named in the past "Red-Weathering Clay-Soil" (1), "Ste. Madeleine Series Soils" (2) and "Talparo Clay Soil" (3) for the Red Soil, and "Princes Town Black Marl Soil" (1), "Hermitage Series Soils" (2) and "Princes Town Heavy Clay Soil" (3) for the Black Soil, and their various attributes and relationships have been described under these terms in the literature cited.

(i) The *Red Soil* is a much leached, highly acid, base-deficient clay. Some of its chemical features are given in Table I. It has been assigned to Grade IV for sugar-cane soils, being of low natural productivity. It is incapable of supporting the proper growth of the best seedling varieties of sugar-cane ("noble" canes), and is therefore mostly used for growing thin-stemmed canes, such as Uba.

(ii) The *Black Soil* is slightly acid in the humic layer. It has developed under heavy rainfall from marlstone containing varying amounts of calcium carbonate. It has been put into Grade I, having high natural productivity. Long-continued cultivation within the undulating lands occupied by Black Soil has aggravated soil-erosion to such an extent that the soil on the hillcrests is relatively shallow so that the parent marly-clay is exposed in many places, showing an ochre-grey colour.

(3) Early fertilizer experiments (1922-1942)

(a) *Historical*: Fertilizer field experiments on sugarcane in the Ste. Madeleine area were first undertaken by G. A. Jones, Company Agronomist, in 1922. When the writer joined the Company in 1927, field experiments had developed to such an extent that a separate section of the Company's organisation had been created for the purpose of conducting the trials. The early experiments soon demonstrated the beneficial results that may be expected from the use of ammonium sulphate. In 1931, the Sugar-Cane Investigation Committee of Trinidad was formed which included a section, under the charge of P. E. Turner, devoted to field experiments on liming and manuring. Since 1934, the majority of the Ste. Madeleine experiments have been carried out in collaboration with this section and the statistical analyses and publication of experimental results has been carried out by its staff (4).

(b) *Some early results*: The early fertilizer experiments demonstrated over a period of years that the optimum dressing of ammonium sulphate was 2 cwt. per acre (about 60 lbs. of nitrogen). The average increase for the BH 10/12 variety of sugar-cane with this dressing was 24 per cent. and for the POJ 2878 variety, 66 per cent., when grown on Black Soil. For the Uba variety grown in those days almost exclusively on Red Soil, it was 63 per cent. Despite these substantial increases in yield, brought about by the use of ammonium sulphate, the average returns per acre were considered not to be satisfactory except for seedling canes grown on Black Soil. For Uba and other thin-stemmed canes such as Co 213, grown on Red Soil, the returns were still very low.

In order to explore the possibility of obtaining still higher yields, field experiments were begun in 1932 to try the effects of phosphatic and potassic fertilizers applied in addition to ammonium sulphate (5). The magnitudes of the dressings of these manures employed, however, were relatively small, and the increments of yield that could be attributed to their use were likewise small. Consequently, phosphatic and potassic manures were not included in the manurial programme applied on a commercial scale for growing sugarcane on the Ste. Madeleine estates

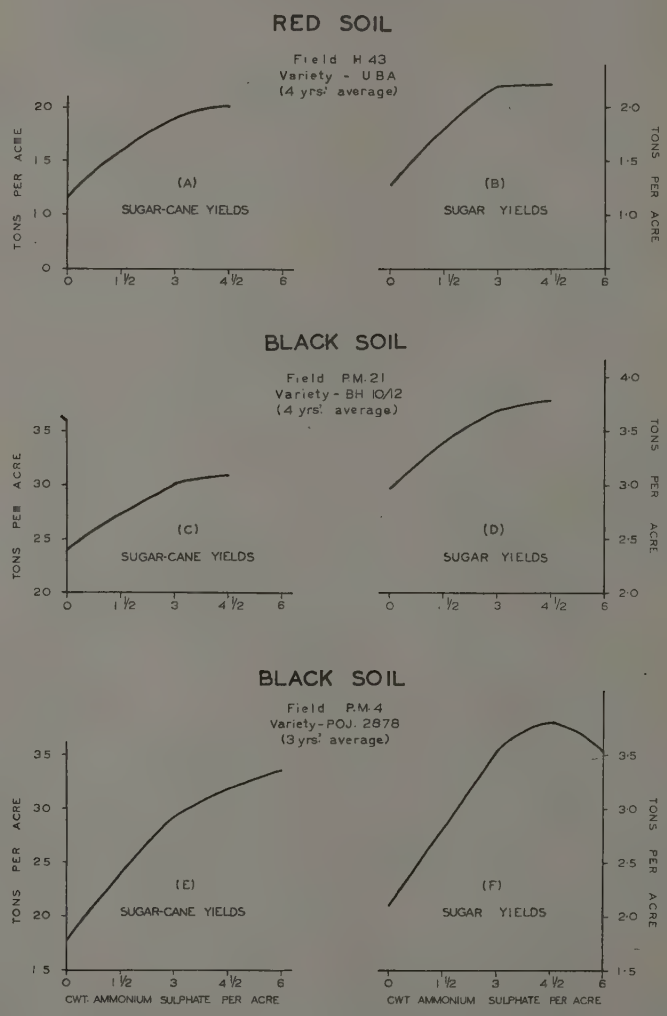
(4) Late fertilizer experiments (1942 and after)

(a) *Chemical tests and pot-tests*: In 1941, at the suggestion of F. Hardy, Professor of Soil Science at the Imperial College of Tropical Agriculture; large representative samples to 9 inches depth of Red Soil and Black Soil were procured for examination by chemical methods and pot-tests from Hermitage Estate (Field 53) and Cedar Hill Estate (Field P.M. 19) respectively. From a hill crest in the last-named field, a sample of eroded soil, comprising highly calcareous soil parent material (grey marl) was also obtained. The main object of the laboratory and greenhouse

STE. MADELEINE SUGAR-CANE EXPERIMENTS

FIGURE I

RESPONSE TO AMMONIUM SULPHATE ALONE



experiments was to investigate the phosphate relationships of the two kinds of soil which are believed to be abnormal in that the standard chemical test for "available" phosphate, namely the Truog test, gives values that are usually not in agreement with those given by pot-tests such as the Mitscherlich test. As a result of this investigation, summarised in a later section, it was found that the phosphate requirements of the Red Soil and of the eroded Black Soil were exceptionally high, of the order of 10 cwt. of superphosphate per acre nine-inches of soil. The phosphate requirement of the uneroded Black Soil was lower, about 4 cwt. per acre. Incidentally, the nitrogen requirements of all three soils were also found to be high, of the order of 8 to 20 cwt. of ammonium sulphate per acre nine-inches of soil but their potash requirements were found to be low, namely, between 1.8 and 0.4 cwt. of potassium sulphate per acre.

(b) *Field experiments based on the results of the pot-tests*: In consequence of these suggestive findings, an attempt was made by the writer to discover whether the same results could be reproduced in the field with sugarcane as the crop. The method consisted in the application of superphosphate manure and ammonium sulphate in graded dosages ranging well above those that had heretofore been customarily employed in the Ste. Madeleine estates. The magnitudes of the increased yields of sugarcane obtained with combinations of high phosphate with high nitrogen treatments on both Red Soil and Black Soil, as well as on eroded Black Soil, were unexpectedly large, even larger than could have been anticipated from the results of the pot-tests. This discovery, if substantiated by subsequent field experience on an estate scale, may completely revolutionise the manurial practices at present in vogue in the Ste. Madeleine sugar-estates. Furthermore, since similar Red and Black soils occur in other parts of the British Caribbean sugar-growing region, the discovery might be directly applicable over a very large area of sugar-cane land. The significance of the discovery cannot fully be realised, however, until a great deal of additional laboratory and field experimentation has been carried out, and it is with the object of stimulating such work that the following preliminary data are herewith published.

PART II

Early Fertilizer Results

It is intended in this section to present some typical results obtained during the first phase of the field investigations in which chief attention was given to the value of ammonium sulphate used as manure for increasing profitably the yield of sugar in the Ste. Madeleine estates.

(A) *RED SOIL*

Field H 43, *Hermitage Estate*: Uba variety *Figure 1*

The graph (Fig. 1 (A)) shows the mean yields per average crop, in tons of sugar-cane per acre, for 11 successive crops grown between 1932 and 1945, comprising five ratoons of one cycle together with plant canes and five ratoons of another cycle. The manurial treatments were 1½, 3 and 4½ cwt. of ammonium sulphate, per acre. The shape of the curve illustrates the law of diminishing returns, the successive increments in yield per crop for each extra 1½ cwt. of fertilizer added being 4.3, 3.0 and 1.15 tons of sugar-cane per acre.

The second graph (Fig. 1 (B)) shows the corresponding yields of sugar, derived by actual juice analysis from the cane yields. With these data, the number of tons of cane required to make one ton of sugar can be calculated. Results so obtained show that it took on the average 9.21, 9.17, 9.08 and 9.56 tons of cane per ton of sugar for the 11 crops with increasing dosages of ammonium sulphate. These figures suggest that the 3 cwt. per acre dosage is best from the point of view of richness of juice. From the point of view of economics, the actual costings data also show the greatest net profit per acre for the 3 cwt. per acre dressing, namely, nearly 19 dollars* per acre, which is about one dollar per acre more than that given by the 4½ cwt. acre dressing.

(B) *BLACK SOIL*

(1) *Field P.M.* 21, *Petit Morne Estate*: BH 10/12 variety, *Figure 1*

The graph (Fig. 1 (C)) shows the average yields per crop for 4 successives ratoon crops, starting with BH the first ratoon reaped in 1933. The manurial treatments were the same as in the last experiment, namely, 0, 1½, 3 and 4½ cwt. of ammonium sulphate per acre. The successive yield increments per crop for each 1½ cwt. of fertilizer added were 3.2, 2.7 and 0.8 tons of sugarcane per acre. Yields of sugar per acre are shown in graph Fig. 1 (D). The number of tons of cane required to make one ton of sugar varied little for the different treatments; the actual figures were, 8.12, 8.10, 8.13, and 8.16. The costings data again show maximum financial benefit (12.8 dollars per acre) from the 3 cwt. dressing, which gave 2.6 dollars per acre more profit than the 4½ cwt. dressing.

(2) *Field P.M.* 4, *Petit Morne Estate*: POJ 2878 variety, *Figure 1*

The graph (Fig. 1 (E)) shows the average yields per crop for three successive ratoon crops, beginning with first ratoons in 1933. The manurial treatments were the same as in the previous experiments, except that a dressing of 6 cwt. per acre was included. The yield differences were 6.3, 5.4, 2.4 and 1.7 tons of sugar-cane per acre. Sugar yields are shown in Fig. 1. (F) which clearly indicates a big drop in richness of juice (sucrose % cane) for the 4½ and 6 cwt. dressings. This means that more tons of cane are needed to make one ton of sugar with the crops

* Note: *One dollar* equivalent to 4s. 2d. sterling

produced by the higher dosages of ammonium sulphate. As regards costings, the net value of the crop per acre increased regularly from 20.6 dollars for the 1½ cwt. dressing to 43.15 dollars for the 6 cwt. dressing, though the increases per 1½ cwt. increase in amount of manure applied diminished rapidly with each successive increment.

The following general conclusions are drawn from experience gained in the first phase of our field investigations in which ammonium sulphate was the only manure used in experiments with different varieties of cane and different stages of growth. The successive increments in yield for the successive dosages of ammonuium sulphate are tabulated below.

Ammonium sulphate Dosage	Percentage increase per 1½ cwt. ammonium sulphate added: Red Soil (Uba)	Black Soil (BH 10/12)	Black Soil (POJ 2878)
0 —1½ cwt. acre	37%	13%	35%
1½—3 ,, ...	19	10	22
3 —4½ ,, ...	6	2.5	8
4½—6 ,, ...	—	—	5.5

(i) The average yields per acre given by Uba cane grown on Red Soil without manure as compared with those given by seedling canes grown on Black Soil without manure were very low, namely, 11.6 tons per acre as against 24.2 tons per acre (BH 10/12) and 17.7 tons per acre (POJ 2878).

(ii) The average yield of Uba on Red Soil with the biggest dressing of ammonium sulphate alone was 20.1 tons per acre (an increase over no manure of 73 per cent.), as against 30.8 (27 per cent. increase) and 33.5 (89 per cent. increase) for BH 10/12 and POJ 2878 respectively on Black Soil. The large response of the Uba and POJ varieties to ammonium sulphate, as contrasted with BH 10/12, is noteworthy.

(iii) In each experiment, the optimum dosage of ammonium sulphate was 3 cwt. per acre.

(iv) As regards richness of juice, evidently the quality of Uba cane grown on Red Soil improved with applications of ammonium sulphate up to 3 cwt. acre but deteriorated markedly with the higher dosage. For canes grown on Black Soil, little impairment of quality occurred except for the highest dressing of 6 cwt. per acre applied to POJ variety.

(v) Profitable returns (of the order of 18 dollars per acre) may be expected from manuring sugar-cane on both Red Soil and Black Soil with ammonium sulphate alone.

PART III

Results of Mitscherlich Pot-Test

In this section, results obtained and described by F. Hardy in two suggestive articles (6), (7), dealing with laboratory studies of representative samples of Red and Black Soils, as well as greenhouse data obtained by the application of Mitscherlich's pot-test, will briefly be discussed. The main experimental results are included in Table I.

TABLE I

Comparison of Results for Red and Black Soils obtained by Chemical Tests and Mitscherlich Pot-Test

(Surface 9-ins. of soil)

Sample	Re-action (pH)	O.M. (%)	C/N	Total (%)	Available Nutrients: Chemical Method NO_3-N (p.p.m.)	P_2O_5	K_2O	Pot-Test Method NO_3-N (p.p.m.)	P_2O_5	K_2O	Manurial Requirements: Diff. from Optim N (cwt. ac.)	P_2O_5	K_2O	Equiv. Manures S/A	Super	S/Pot
Red 1 ...	4.7	2.1	7.4	0.17	†85	7	137	157	1	100	2.00	1.75	0.45	11.0	9.7	0.9
Red 2 ...	4.6	1.5	6.1	0.15	75	12	137	—	1	67	—	1.74	0.40	—	9.7	0.8
Black 1 ...	6.5	4.9	11.3	0.25	125	75	219	67	61	62	3.61	0.66	0.50	18.0	3.7	1.0
Black 2 ...	*7.5	1.6	8.3	0.11	55	11	119	49	9	78	3.92	1.59	0.20	19.6	8.8	0.4

* $CaCO_3$, 23.6 per cent † Assuming 5% nitrifying efficiency.

Limits of adequacy arbitrarily accepted for sugar-cane: P_2O_5, 30 p.p.m., K_2O, 150 p.p.m.

Red Soil 1: Hermitage, H 53. *Red Soil 2*; Ben Lomond, B/L. 38

Black Soil 1: Cedar Hill, PM 19. *Black Soil 2*; ditto. eroded phase.

Description of the Soils

(A) *Red Soil*: This is a highly acid silty-clay often containing up to 85 per cent. of clay. The red colour(really salmon-pink) usually extends only to 12 inches depth, below which it merges into greenish-grey, mottled crimson and reddish-brown, and finally into uniform dark blue-grey below about the 10-foot depth. Drainage is internally impeded because of the clayey texture, and percolation mainly takes place through natural cracks. Pedologically, this soil type might be assigned to the "Red Podzolic" Zonal group in the modern American classification (8).

The amounts of organic matter and nitrogen in the top 9-inch layer are low and carbon-nitrogen ratios are very low, the profile having been deeply truncated by erosion. Available phosphate (Truog method) is low to very low, and available potash (exchangeable potash) is medium-low. The lime requirement for complete saturation by calcium, calculated from exchangeable calcium contents, is about 6 tons of ground limestone per acre nine inches. Assuming an average value of 5 per cent. for the nitrifying efficiency of the total nitrogen present, the surface 9-inch layer of typical Red Soil shows a content for available nitrogen (NO_3-N) of around 80 p.p.m.

The results of the Mitscherlich pot-test (6) agree reasonably well with the chemical data, except that available nitrogen content seems to be somewhat higher as gauged by the pot-test. This may perhaps be accounted for by a higher rate of nitrification than that which was arbitrarily employed for converting total nitrogen to available nitrogen (namely, 5 per cent.), which indeed is suggested by the low carbon-nitrogen ratio believed to be conducive to high nitrate production.

The theoretical *manurial requirements* of the Red Soil samples (Table I) are apparently very high for nitrogen and phosphate but low for potash. The suggested dressings of standard manures needed to bring the soils to a state of high fertility are of the order of 10 cwt. per acre of ammonium sulphate and superphosphate respectively. It should be especially noted, however, that very little growth was obtained in the Sudan Grass Mitscherlich cultures of Red Soil *except when the soil was previously limed.*

(B) *Black Soil*: This is a slightly acid silty-clay generally containing over 90 per cent. of clay. The black colour extends to 6, 12, 18 or more inches, depending on topography and degree of profile truncation by erosion. Below, the colour changes sharply in the non-humic clay to grey, greyish-ochre or golden-yellow, and in the parent rock to white or cream. The lower part of the yellow parent clay or the upper part of the parent marlstone usually contains white concretions of calcium carbonate, presumably carried down by leaching. The fracture planes of the parent rock may be stained sepia or black by manganese peroxide and rusty-brown by limonite. Internal drainage is impeded. Pedologically, this soil-type would be classed as Rendzina (Intrazonal, Calcimorphic) according to the modern American system (8).

The contents of organic matter and nitrogen in the top soil sample are medium-high with high carbon-nitrogen ratio. They are low in the eroded sample of exposed subsoil. Available phosphate content (Truog method) is apparently relatively high in the humic soil but very low in the subsoil. Available potash content is medium-high and presumably adequate in the topsoil but low and inadequate in the eroded sample. The humic soil is 70 per cent. saturated by exchangeable calcium. It contains 15 per cent. of exchangeable magnesium on total base exchange capacity. There is no lime requirement. The available nitrogen content is theoretically about 125 p.p.m NO_3-N which is relatively very high.

The Mitscherlich pot-test results for the black topsoil (7) show a marked deficiency of available nitrogen, in spite of the high content of total nitrogen. This is a well-known feature of Rendzina soils and is associated with high carbon-nitrogen ratio. Nitrogen seems to be largely "locked up" in unavailable form in this kind of soil, so that it usually responds readily to soluble nitrogenous manures. The Mitscherlich data for available phosphate show a fairly high phosphate content though not quite so high as that given by the chemical test. In the absence of phosphatic manure, however, the Sudan Grass Mitscherlich cultures gave only about one-half the yield given by the complete nutrient cultures, suggesting marked phosphate shortage.* The pot-test results for available potash were also lower than those obtained by chemical means. For the eroded soil, the pot-test results agree fairly well with the chemical data. The theoretical *manurial requirements* of the Black Soil samples (Table I) are extremely high for nitrogen (nearly 20 cwt. per acre of ammonium sulphate) and for phosphate very high in the eroded soil (9 cwt. acre superphosphate) and medium-high in the black topsoil (4 cwt. acre). The potash requirement is low in each case.

It must be stressed that the Mitscherlich pot-test cannot unreservedly be accepted as a method for accurately assessing the nutrient contents of soils and for deriving their exact manurial requirements under tropical conditions with test-plants other than the standard oats used in Germany (9). Nevertheless, the very striking results obtained with the Ste. Madeleine soils demonstrate at least that the Red Soil and the Eroded Black Soil are extremely deficient in available nitrogen and phosphate, and may need heavy dressings of appropriate manures in order to produce maximum yields of sugarcane. They also suggest that the uneroded Black Soil may likewise need larger dressings of phosphatic manure than have heretofore been applied to them if maximum benefit from nitrogenous manure is to be realised.

* The Mitscherlich cultures *containing no added phosphate* gave practically no crop at all in the case of the Red Soils and the eroded Black Soil, as is clearly shown the photographs illustrating the published papers (6), (7).

PART IV

Recent Fertilizer Results

It is intended in this section to describe field manurial experiments carried out on Red Soil and Black Soil (both normal and eroded) in which graded dosages of nitrogenous and phosphatic manures were applied in combination. This phase of the experimental work began in 1942.

(A) *RED SOIL*

(1) Field H 54, Hermitage Estate: B 34104 variety. *Figure 2*

This field is next to that from which the pot-test sample was taken and its soil closely resembles the tested soil. The field had been growing Uba cane for many years before the new phosphate experiment was laid down. The successive crops had each been manured with 2 or 3 cwt. of ammonium sulphate per acre according to routine estate practice. The yields varied between 38 tons per acre for plants (1933) and 12 tons per acre for fourth ratoons. In 1938, ground limestone was applied at the rate of 5 tons per acre. The field was tractor disc-ploughed to 15 inches depth before each replanting in 1931, 1938 and 1942. The beds, 22 feet wide, were made with a tractor-drawn road grader. The cane setts were planted in the wet season in furrows dug across the beds.

Field procedure: The phosphate experiment was initiated in March, 1942, when the field was last ploughed for replanting. The land lay fallow until planted with B 34104 canes in November. Ground limestone was spread, 10 tons to the acre, one month before planting. Fertilizers were applied around the young plants in mid-December. The banks were then broken into the furrows so as to bury the manure and to level off the land. The customary weedings were carried out during the growth of the crop. Measurements of cane length and of number of stems per stool were made when the plants were 4 months old. The crop was reaped in April, 1944, when 16 months old. The trash was burnt off before cutting. Five canes from each plot were collected at random for juice analysis.

The *first ratoon* crop was likewise manured in May, 1944, and similar growth measurements were made when the canes were 6 months old. The ratoon crop was reaped at the end of March, 1945, when 10 months old.

Lay-out: The experiment was laid out in 4 randomised blocks of 12 treatments giving 4 replicates of each treatment, both with and without liming. Each plot was 1/40 acre and consisted of 10 rows of canes planted in 5 pairs across the bed.

Fertilizer treatments: Four levels of superphosphate, (18 per cent. P_2O_5), namely, 0, 3, 6 and 9 cwt. per acre, and three levels of ammonium sulphate (20.6 per cent. N) namely, 2½, 5 and 7½ cwt. per acre, were applied to the plant canes on the basis of the results of the chemical tests and the pot-tests. For the ratoon crop, the same phosphate treatments were used but the ammonium sulphate dressings were raised to 3, 6 and 9 cwt. acre.

Yields Results: The yields obtained are shown in Fig. 2 for limed and unlimed plots and for plant-canes and first ratoon canes respectively. The trends of the data are somewhat irregular but they clearly indicate the greatly increased yields that can be obtained with different dosages of ammonium sulphate when increasing dosages of superphosphate are also added. Thus, in the *unlimed* plots growing B 34104 plant-canes (Fig. 2 (A)) a maximum yield of 57 tons per acre was obtained with 7½ cwt. ammonium sulphate and 6 cwt. superphosphate. With no superphosphate added, this dosage of nitrogenous manure gave 45¾ tons per acre of sugar-cane. In the *limed* plots (Fig. 2 (B)), the corresponding yields were 55½ tons and 45½ tons per acre, which differ but little from those given by the unlimed soil.

> NOTE: This result does not agree with the pot-test results in which liming was found to be essential for the growth of the indicator plant. The discrepancy may be explained by the fact that the limestone may not have completely reacted with the soil in the field in the short time that had elapsed between its application and the planting date. It could also be explained by assuming that the indicator plant (Sudan Grass) requires a neutral reaction or abundant nutrient calcium for satisfactory growth.

Similar results were obtained with the *first ratoon crop*. In the *unlimed* plots, the addition of 3 cwt. superphosphate raised the yield given by 9 cwts. of ammonium sulphate per acre from 31 tons to 40½ tons per acre, and in the *limed* plots, from 35 tons to 39½ tons per acre. In both cases there was little to choose between the efficacy of the different dosages of superphosphate, possibly because of the residual effects of the previous phosphate treatments.

With the customary estate manuring of 2½ or 3 cwt. of ammonium sulphate per acre applied alone, the yields per acre for plant-cane in this field would be around 37½ tons without lime and 39¼ tons with lime. For first ratoons they would be about 28 tons and 30½ tons per acre respectively. Thus, by replacing the usual estate manurial treatment by a high phosphate-high nitrogen treatment, *additional increases* in yield for plant-canes of 52 per cent. in the absence of lime and 40 per cent. where lime is used, and for first ratoons of 43 and 28 per cent., could reasonably be expected.

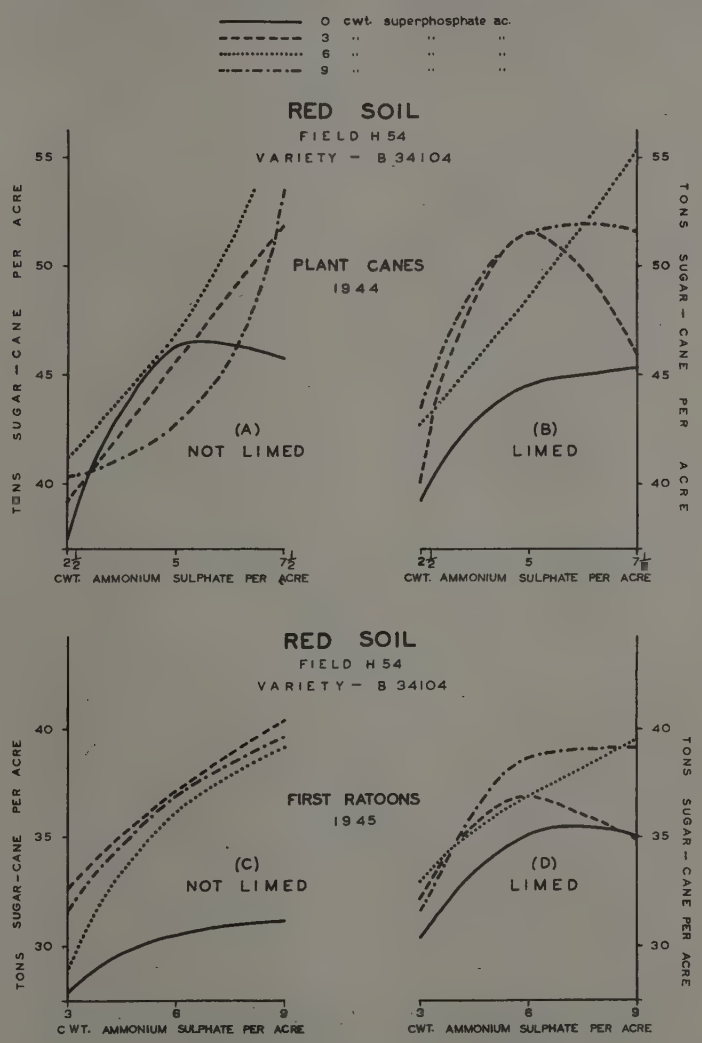
Costs: After allowing for the costs of the manure applications* and of reaping the increased crops, the total net profits from the optimum dressings of

* The value of sugar-cane was taken as $5.50 per ton, of ammonium sulphate $4.00 per cwt., of superphosphate, $2.50 per cwt. and of ground limestone, $7.50 per ton. The costs of manure application were taken as 60 cents per 1 to 4 cwt. acre, increasing according to a sliding scale approximately by 10 cents for each additional dosage of 3 cwt. per acre. The cost of reaping was taken as 1.20 dollars per ton of cane.

STE. MADELEINE SUGAR- CANE EXPERIMENTS

FIGURE 2

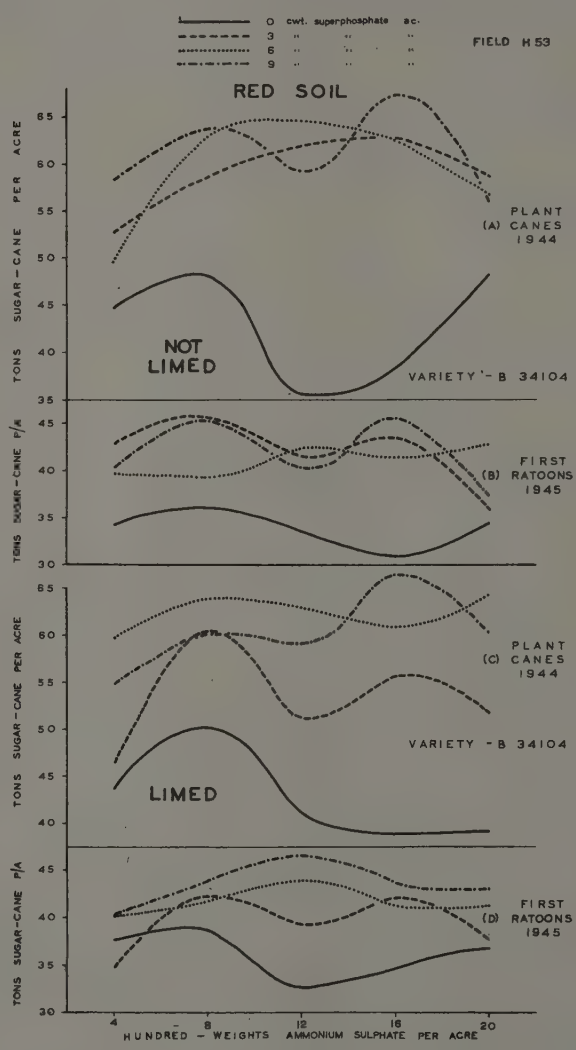
RESPONSE TO AMMONIUM SULPHATE & SUPERPHOSPHATE



STE. MADELEINE SUGAR-CANE EXPERIMENTS

FIGURE 3

RESPONSE TO AMMONIUM SULPHATE & SUPERPHOSPHATE



phosphatic and nitrogenous fertilizers in the absence of lime, as compared with the usual routine estate manuring, were 48.5 dollars per acre for plant-canes and 21.5 dollars for ratoons, and in the presence of lime, 33.5 and 8.0 dollars per acre respectively. Other combinations of manures also gave highly remunerative returns.

(2) *Field H 53, Hermitage Estate*: B 34104 variety. *Figure 3*

This field is the one from which the pot-test soil samples were actually taken. Its previous history, treatment and yielding capacity for Uba cane are similar to those for Field H 54, last considered.

Field procedure: The phosphate experiment was initiated in March, 1942, when the field was last ploughed for replanting. The cane furrows were dug in October and ground limestone, 10 tons per acre, was applied in November by hand. Fertilizers were placed in the furrows in December and lightly forked in. The cane setts, B 34104 variety, were then planted along the furrows. Subsequently, soil was hoed into the furrows so as to bank up the growing canes. The crop was reaped without trash burning in late April, 1944, when 16 months old. Samples were collected for juice analysis, and the number of stems per stool was counted.

The *first ratoon* crop was manured similarly and the crop was reaped in late March, 1945, when 11 months old.

Lay-out: There were 8 randomised blocks each containing one replicate of each of 20 treatments. Four alternate blocks were limed. Each plot was 1/400 acre in area and consisted of one row of 10 cane plants.

Fertilizer treatments: Four levels of superphosphate (18% P_2O_5), namely, 0, 3, 6 and 9 cwt. per acre, and 5 levels of ammonium sulphate (20.6% N), namely, 4, 8, 12, 16 and 20 cwt. per acre, were applied to plant-canes and to first ratoons.

Yield results: These are shown in Fig. 3 for limed and unlimed plots.

In the *unlimed* plots growing plant-canes (Fig. 3 (A)), it will be noted that, with no superphosphate added, the yield rose slightly from nearly 45 tons to just over 48 tons per acre for the 4 and the 8 cwt. dosages of ammonium sulphate, but fell to less than 36 tons per acre with the extra addition of 4 cwt. acre more fertilizer. With the next 4 cwt. extra dosage, the yield rose again to about 38 tons, and with the next, to over 48 tons. These peculiar fluctuations in yield, namely, an elevation followed by a large depression followed by another elevation, cannot fully be explained on available evidence, but it is suggested that the depression may have been caused by the toxic action of excessive amounts of nitrate produced by the rapid nitrification of the large dressing of ammonium salt, and the elevation following may have been caused by a change from nitrate to ammonium nutrition as ammonium-ion accumulated in excess over nitrate at the highest concentrations of manure.

The effect of superphosphate in raising the yield of plant-canes treated with the higher dosages of nitrogenous fertilizer in the absence of lime is clearly shown by the graphs (Fig. 3 (A)). Here again, however, the irregularities are difficult to explain. For dosages of ammonium sulphate up to 12 cwt. per acre, maximum effect appears to have been given by the 6 cwt. per acre dressing of superphosphate which raised the yield to 64½ tons of plant-cane per acre and showed no depressing effect. With a routine estate dressing of 4 cwt. of ammonium sulphate per acre, the yield was about 45 tons per acre, so that the increment in yield, attributable to high phosphate-high nitrogen manuring, was 19¾ tons per acre, or 44 per cent.

Similar results were obtained with the first ratoon crop (Fig. 3 (B)). In the absence of superphosphate, the increasing dosages of ammonium sulphate first gave a slight increase in yield followed by a considerable depression and then by a rise to practically the same level as the starting point. Evidently there is no advantage in applying more than 4 cwt. per acre of ammonium sulphate alone. With superphosphate added, however, the yielding capacity was raised to a much higher level, but there seems to be no advantage in applying more than 3 cwt. per acre of superphosphate in order to obtain maximum results, probably because of the residual effect of phosphatic manure previously added. With this amount of phosphatic manure, 8 cwt. per acre of ammonium sulphate gave 45½ tons per acre of plant-cane, an increase of 10½ tons (or 30 per cent.), attributable entirely to the "boosting" effect of the added phosphate.

In the *limed* plots growing plant-canes (Fig. 3 (C)), the yield rose from about 44 tons to 50 tons per acre with the first 4 cwt. increment of ammonium sulphate, when no superphosphate was added. It dropped very low with further increments of nitrogenous manure. When superphosphate was added, not only were the yields given by the 4 and the 8 cwt. dosages ammonium sulphate greatly raised, but also the depressing effect on yield of the higher dosages of nitrogenous manure was overcome and much greater increments in yield were consequently attained. In this experiment, best results were given with the 6 cwt. per acre dressing of superphosphate, which raised the yield given by 4 cwt. of ammonium sulphate from 44 to nearly 60 tons (a 36 per cent. increase), and that given by 16 cwt. from 39 to 61 tons per acre (a 56 per cent. increase).

The results obtained with first ratoons (Fig. 3 (D)) again were qualitatively, though not quantitatively, similar. The yield given by 4 cwt. of ammonium sulphate per acre, applied alone to the

limed soil was 37½ tons, and it was raised to 40 tons per acre (6 per cent. increase) by dressings of 6 or 9 cwt. of superphosphate. That given by 12 cwt. of nitrogenous manure alone was raised from 32¾ to 46½ tons by the addition of superphosphate, 9 cwt. per acre, and to 44 tons per acre by the 6 cwt. dosage, increases of 42 per cent. and 35 per cent. respectively.

Costs: In this experiment, the nett profits again proved to be very large for the optimum treatments involving superphosphate. Thus, for *unlimed* soil growing plant-canes the combined 6 cwt. superphosphate 8 cwt. ammonium sulphate treatment gave a nett profit of 46.3 dollars and the 6 cwt. x 12 cwt. treatment a profit of 37.3 dollars an acre. Several other combined high treatments gave equally large financial returns. For first ratoons, the 3 cwt. x 4 cwt. treatment gave 28.7 dollars, profit and the 3 cwt. x 8 cwt. treatment gave 24.6 dollars per acre profit.

For *limed* soil, plant-canes grown with the 3 cwt. superphosphate x 8 cwt. ammonium sulphate treatment gave a net profit of 46.7 dollars per acre. With the 6 cwt. x 4 cwt. treatment, the profit was 52.3 dollars. With the 6 cwt. x 8 cwt. treatment, it was 54.0 dollars, and with the 6 cwt. 12 cwt. treatment it was 34.3 dollars. First ratoons, however, gave no profit in the limed plots. The least loss (4.9 dollars an acre) was given by the 3 cwt. x 8 cwt. treatment. The increments in yield given by other treatments, though considerable, involved large dressings of manure whose cost was too great to offset the value of the extra crops.

(B) *BLACK SOIL*

Field P.M. 19, Cedar Hill Estate

The topography of the field on which the Black Soil phosphate experiments were carried out is undulating and the soil on the crests is shallow because of erosion whereas in the hollows it is deep. The shallow eroded soil produces poor plant-cane crops. Furthermore, the ratoon crops soon die out and weeds, mainly Railway Daisy (*Bidens pilosa*), rapidly cover the ground. By contrast, the deep bottom soils support excellent crops, both of plant-canes and of ratoons. The field *as a whole* since 1930 has given yields of plant-cane up to 38 tons per acre and yields of about 13 tons per acre for old ratoons. Manuring in the past customarily consisted in the application of 15 tons of pen manure and 2 cwt. of ammonium sulphate per acre to plant-canes, and 2 cwt. of ammonium sulphate alone to each successive ratoon crop. Routine cultivation consists in tractor disc-ploughing to 15 inches depth. Ploughing was carried out before replantings in 1930, 1938 and 1942. The cane beds are formed by a tractor-drawn road grader, and the furrows are made by hand-forking in the wet season just before planting. Pen manure is placed in the furrows when the plants are a few weeks old and the soil is hoed down over it. Ammonium sulphate is sprinkled round the young cane plants.

Phosphate experiments were initiated in this field in March, 1942, when the field was last ploughed and the banks constructed. The furrows were dug in early November for planting. One experiment was laid down on a hill-crest on shallow eroded soil and another in a hollow on deep soil.

(1) *SHALLOW ERODED SOIL*

Variety B 34104 *Figure 4*

The site of this experiment was the same as that from which the pot-test sample of eroded grey marl soil was taken in 1941.

Field procedure: The cane setts were planted in pairs, 5 in number, each 4½ feet apart and each plant in a pair, 2½ feet apart. Sweet potato slips were planted on alternate banks but the vines were cut and buried by hoeing before they were fully grown. The complete dressings of superphosphate and half the dressings of ammonium sulphate were sprinkled around the cane plants in early December, 1942, when they were about four weeks old. The manures were covered by breaking alternate banks by hoeing. The remainder of the nitrogenous manure was applied at the end of January, 1943, and the soil of the untouched banks was finally hoed down over it. The land was subsequently weeded when needed.

The trash was burnt at the beginning of May, 1944, and the crop was reaped immediately after, when 18 months old. No growth measurements nor juice analyses were made.

First ratoons were manured in the same manner as the plant-canes. The ratoon crop was reaped in early June, 1945, when 12 months old.

Lay-out: The experiment was laid out as six randomised blocks with 16 treatments, each replicated six times. Each plot consisted of four rows of cane with area 1/100 acre. Only 5 blocks of canes were actually weighed. The cane variety grown was B 34104.

Fertilizer treatments: Four levels of superphosphate and of ammonium sulphate were selected, namely, 0, 3, 6, and 9 cwt. for the one and 5, 10, 15 and 20 cwt. per acre for the other, in accordance with the results of chemical and pot-tests. These dressings were applied both to plant-canes and first ratoons.

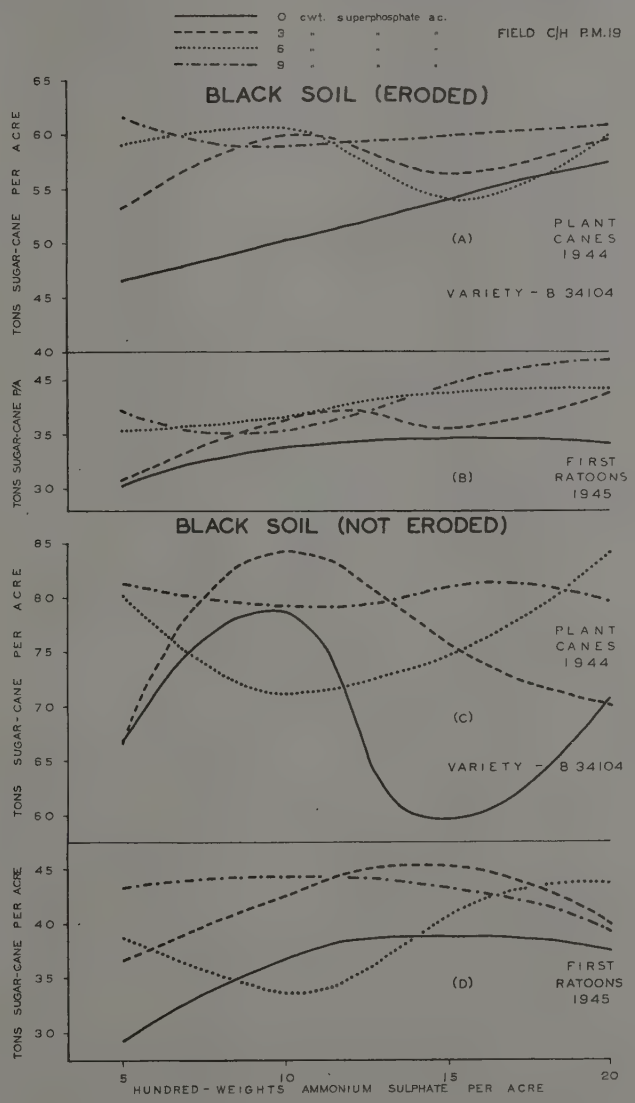
Yield results: These are plotted in Fig. 4 (A) for plant-canes, and Fig. 4 (B) for first ratoons.

The yields of plant-canes grown with different dosages of ammonium sulphate alone show a straight line relationship. Maximum increment (given by the 20 cwt. dressing) was 11 tons of cane per acre (or 24 per cent.) over a basal yield of 46½ tons for the smallest dressing of 5 cwt. acre. With superphosphate added, the general level of the yields was raised considerably, particularly for the lower dosages of ammonium sulphate. Best results were given by the 9 cwt. dressing of superphosphate, though this proved not to be much superior to the 6 cwt. dressing. With these heavy dosages of phosphatic manure, the plant-cane yield given by the smallest dressing of ammonium sulphate of 5 cwt. was raised from 46½ tons

STE. MADELEINE SUGAR-CANE EXPERIMENTS

FIGURE 4

RESPONSE TO AMMONIUM SULPHATE & SUPERPHOSPHATE



to around 60½ tons per acre, an increase of 30 per cent., attributable to phosphate. With 10 cwt. of ammonium sulphate, all three superphosphate treatments gave about the same increment, raising the yield of plant-canes from 50¼ to about 60 tons per acre, an increase of 19.5 per cent. With the 15 cwt. dressing of nitrogenous manure, the phosphate effect was greatest with 9 cwt. of superphosphate, which raised the yield from 54 to 60 tons per acre, an 11 per cent. increase. With the 20 cwt. dressing, the phosphate effect was negligible.

The *first ratoon* results (Fig. 4 (B) were similar. Here again the 9 cwt. dressing of superphosphate was the most efficacious, but it was not greatly superior to the other dressings. The maximum yield increment for the 5 cwt. dressing of ammonium sulphate was 7 tons for a no-phosphate yield of 30 tons per acre (23 per cent. increase). For the higher dosages of nitrogenous manure, the maximum phosphate yield increments were 8, 15 and 23 per cent., given mostly by the 9 cwt. dressing of superphosphate, though this was not much superior to the other treatments.

Costs: Highest nett profit with *plant-canes* in this experiment on eroded marl soil was given by the 9 cwt. superphosphate × 5 cwt. ammonium sulphate combination, namely 42.3 dollars per acre, over the cost of the manurial treatment consisting of 5 cwt. of ammonium sulphate, the routine estate treatment being 3 cwt. per acre. The next highest profit was given by 6 cwt. super x 5 cwt. ammonium sulphate, namely, 38.0 dollars per acre. Some other combinations, for example, 3 cwt. x 10 cwt., 6 cwt. x 10 cwt., 3 cwt. x 5 cwt. and 9 cwt. x 10 cwt., also gave substantial profits, ranging from 30 to 10 dollars an acre. For *first ratoons,* only the 9 cwt. superphosphate x 5 cwt. ammonium sulphate and the 6 cwt. x 5 cwt. combinations were profitable but the nett gain was only about 7 dollars per acre.

(2) *DEEP SOIL* Variety B 34104, *Figure 4*

The site of this experiment also was the same as that at which the pot-test soil sample of deep black soil was collected.

Field procedure: *Lay-out*: *Fertilizer treatments*: These were identical with those employed in the last experiment.

Yield results: The data for plant-canes and first ratoons are plotted in Fig. 4 (C) and (D). The yields of plant-canes for different dosages of ammonium sulphate alone showed the same large fluctuations as for Red Soil, namely, a large increase for the first fertilizer increment followed by a large decrease for the second, followed by an increase to near the starting level for the third. The first increase in yield was from 66½ to 78¾ tons per acre (18 per cent.) and it was the only significant increase given by ammonium sulphate alone above the yield given by a dressing of 5 cwt. per acre.

The effect of adding superphosphate to the ammonium sulphate treatments was well marked and its magnitude was unexpectedly large. With the 5 cwt. ammonium sulphate dressing, both the 6 and the 9 cwt. superphosphate dressing raised the yield of plant-canes from 66½ to 80¼ tons per acre, an increase of 21 per cent. By contrast, the 3 cwt. superphosphate dressing had no effect whatever.

The phosphate effect for the 10 cwt. ammonium sulphate treatment was erratic, but the phosphate effect for the 15 cwt. basal treatment of ammonium sulphate was very great, chiefly because the ammonium sulphate treatment alone (without phosphate added) greatly depressed the yield. Here the 9 cwt. superphosphate dressing raised the yield from about 60 to 81 tons per acre, an increase of 35 per cent. The 6 cwt. and the 3 cwt. dressings each raised the yield to about 75 tons per acre, an increase of 25 per cent. With the 20 cwt. ammonium sulphate treatment, the 3 cwt. superphosphate dressing had no effect, but the 6 and the 9 cwt. dressings raised the yield from 70½ to about 82 tons per acre, or 16 per cent.

Results for the *first ratoon* crop were irregular. The dressing of 5 cwt. ammonium sulphate alone gave a yield of 29½ tons, whereas 10 cwt. gave about 37 tons, 15 cwt. gave 38¾ tons and 20 cwt. gave 37½ tons of ratoon cane per acre. Only the first increment is appreciable.

The effects of superphosphate in raising the general yields of ratoon cane given by nitrogenous manure again were considerable. Thus, with a basal dressing of 5 cwt. of ammonium sulphate, 3 cwt. of superphosphate raised the yield from 29½ to 36½ tons (24 per cent. increase), whilst 6 cwt. raised it to 38¾ tons (32 per cent.) and 9 cwt. to 43½ tons per acre (47 per cent.). With 10 cwt. of ammonium sulphate as basal dressing, the increases in yield of ratoon cane given by 3 and 9 cwt. of superphosphate were each about 6½ tons per acre (17 per cent.) but no increase was given by the 6 cwt. dressing of superphosphate. Similar irregularities are shown in the graphs (Fig. 4 (D)) for the phosphate effect for basal dressings of 15 and 20 cwt. of ammonium sulphate. The lines in the graphs for different dosages of superphosphate are convergent, indicating that the phosphate effect is relatively less the bigger the basal amount of nitrogenous manure added. Maximum phosphate effect was given with the 5 cwt. per acre basal dressing of ammonium sulphate.

Costs: Highest nett profit for plant-canes grown on deep Black Soil in this experiment was afforded by the 3 cwt. superphosphate x 10 cwt. ammonium sulphate combination which produced 47 dollars per acre more profit than 5 cwt. of ammonium sulphate alone, the routine estate treatment being 3 cwt. per acre. The next largest profit, 42 dollars per acre, was given by the 6 cwt. x 5 cwt. combination, and the next, 41.5 dollars, was given by the 9 cwt. x 5 cwt. mixture. The 10 cwt. ammonium sulphate alone

dressing gave a nett profit of 30.3 dollars per acre over the 5 cwt. ammonium sulphate dressing. The only other remunerative treatment in this experiment with plant-canes was the 9 cwt. x 10 cwt. combination, which gave 10.3 dollars profit. All the other treatments gave a loss.

For *first ratoons,* half the number of combined phosphatic and nitrogenous manurial treatments gave profitable returns ranging from 37.2 to 19.3 dollars per acre. In each case, the profits were more than twice as great when superphosphate was included in the manurial dressing than when ammonium sulphate was applied alone.

Summary of Yield Data and Costings

The main results reported in the text are brought together in Table II for plant-canes and first ratoon canes growing on Red Soil and Black Soil respectively.

In Column 1 of the table, the optimum treatments are expressed in terms of superphosphate cwt. per acre and of ammonium sulphate cwt. per acre. Thus 6 x 7½ implies a combined treatment involving 6 cwt. per acre of superphosphate (Super) and 7½ cwt. per acre of ammonium sulphate (S/A). Yields given by the optimum treatments are given in Colum 2 as tons per acre of cane. Yields given by the ammonium sulphate dressings alone of the optimum treatments are given in Column 3, and yields given by the usual routine estate ammonium sulphate treatment (2 or 3 cwt. per acre), or where not included in the experimental treatments, by the lowest dosage of ammonium sulphate used, are given in

TABLE II

SUMMARY OF MAIN RESULTS OF THE PHOSPHATE EXPERIMENTS ON RED SOIL AND BLACK SOIL

Experiment	1	2	3	4	5	6	7
	Optimum treatment (Super x S/A)	Maximum yield	Yield with no super but same S/A dressing	Yield with routine estate treatment of S/A alone	Percentage increase from optimum treatment		Total profit per ac. over estate treatment
					Due to Super	Over estate treatment	
	(cwt. ac.)	(tons. ac.)	(tons. ac.)	(tons. ac.)			(dollars)
			RED SOIL				
PLANTS : Var. B34104							
(1) H 54 Unlimed ...	6 x 7½	57	45¾	37½	25%	52%	$ 48.5
(2) H 53 Unlimed ...	6 x 12	64½	35¾	44¾	80	44	46.3
(1) H 54 Limed ...	6 x 7½	55½	45½	39¼	22%	41%	$ 33.5
(2) H 53 Limed ...	6 x 4	59¾	39	44	53	36	52.3
			BLACK SOIL				
(1) PM 19 Eroded ...	9 x 5	60½	46½	(38)	30%	(60)%	$ 42.3
(2) PM 19 Deep ...	6 x 5	80¼	66½	66½	21	21	47.0
			RED SOIL				
FIRST RATOONS : Var. B34104							
(1) H 54 Unlimed ...	3 x 9	40½	31	28	31%	45%	$ 21.4
(2) H 53 Unlimed ...	3 x 8	45½	35	34½	30	33	24.6
(3) H 54 Limed ...	6 x 9	39½	35	30½	12%	28%	$ 8.0
(4) H 53 Limed ...	9 x 12	46½	32¾	37½	42	24	—
			BLACK SOIL				
(1) PM 19 Eroded ...	9 x 5	37	30	(27)	23%	37%	$ 7.0
(2) PM 19 Deep ...	9 x 5	43½	29½	29½	47	47	37.2

Column 4. In Column 5 are given the percentage increases that can be attributed solely to superphosphate applied in appropriate dosages, reacting with appropriate ammonium sulphate dressings to give the optimum response. In Column 6 is given the excess of the optimum yields over the yields given by the routine estate treatment, or by the smallest dressing of ammonium sulphate applied alone.

It will be seen that the *percentage increases* due to phosphatic manure, though irregular, are all (except one) over 20 per cent.; they are highest in comparison with yields obtained by the routine estate treatment. Biggest responses were obtained with plant-canes. The ratoon crop probably benefited somewhat from the residues of phosphate from the large dressings of superphosphate given to the plant-canes. Responses were greater with plant-canes growing on Red Soil as compared with Black Soil but the reverse is true for first ratoons.

The *nett profits* were very high for plant-canes, of the order of 45 dollars per acre, or nearly £10 (pounds) sterling. For first ratoons, they were much less, about 18 dollars per acre or £3. 15s. 0d.

Degree of Tillering on Red Soil

The main visible, above-ground, effect of high phosphate-high nitrogen manuring was found by field observations to be a relatively *large increase in tiller counts* for canes growing on Red Soil. (No counts were made in the Black Soil experiments but casual observation showed that it occurs there also). The magnitudes of the maximum and the minimum tillering effects, determined by actual counting in different experiments on Red Soil, are shown in Table III., in which average tiller counts per 10 stools of cane are given. The manurial combination which produced each result is indicated in brackets as cwt. per acre for superphosphate and ammonium sulphate dosages. The percentage increases in number of tillers are compared in the last column.

It will be noticed that, in Table III, the minimum tiller counts were given by treatments which included no superphosphate but consisted solely of large dressings of ammonium sulphate. The mean relative increase in the number of tillers resulting from the high phosphate high nitrogen treatments was nearly 50 per cent. It was apparently lowest for first ratoons growing on Red Soil in the first experiment on Field H 54 (about 25 per cent.). Ratoons growing on Red Soil in the second experiment (H 53) produced many more tillers than did the plant-canes. Liming appears to have been responsible for a slight but irregular increase in tilering (about 10 per cent).

The increased yield of canes obtained on Red Soil at cropping time may be attributed to the stimulating effect on the root system of the sugar-cane of the high dosages of soluble phosphatic manure applied around the base of the plant. The concentration of phosphate was doubtless sufficiently large to have overcome locally the high phosphate-fixing capacity of the active ferruginous component of the Red Soil, which, from laboratory measurements on similar soils, may exceed one ton of superphosphate per acre. When abundant nitrogen is also available in the vicinity, the large number of tillers which result are enabled to grow to maturity. The final crop therefore consists of a dense population of stems of similar size and degree of maturity. This in theory should tend to produce a more uniform and richer juice and therefore to result in a smaller weight of canes needed to make a ton of sugar.

TABLE III

NUMBER OF TILLERS PER 10 STOOLS: RED SOIL

	Maximum (10 stools) (Super x S/A)	Minimum (10 stools) (Super x S/A)	Percentage increase in tillering
	RED SOIL		
H 54: Plants	Unlimed 136 (6 x 7½) Limed 139 (9 x 7½)	92 (0 x 2½) 87 (0 x 7½)	47% 60
1st. Rats.	Unlimed 105 (6 x 6) Limed 114 (9 x 9)	85 (0 x 3) 91 (0 x 6)	24% 25
H 53: Plants	Unlimed 73 (9 x 8) Limed 75 (6 x 20)	49 (0 x 12) 49 (0 x 16)	49% 53
1st. Rats.	Unlimed 117 (9 x 12) Limed 145 (9 x 12)	82 (0 x 16) 89 (0 x 12)	43% 63

Production of Sugar per Acre : Red Soil

From the yield data and the results of juice analysis performed on representative samples of cane separately collected from the different plots of the two experiments on Red Soil, the actual yields of *sugar per acre* have been calculated. Results so obtained have considerable commercial importance, since they express the sugar producing capacity of the soil under manurial treatment in its simplest terms. The derived data are brought together in Table IV in which the effects of the different combinations of phosphatic and nitrogenous fertilizers are compared on a percentage basis in terms of sugar yields.

TABLE IV

SUGAR-PRODUCTION PER ACRE : RED SOIL : PLANT-CANES AND FIRST RATOONS, B 34104

(Results for combinations of phosphatic and nitrogenous fertilizers)

	Super S/A (cwt. ac.)		UNLIMED			LIMED				
			Tons cane per ton sugar	Average yield of sugar (tons. ac.)	Percentage yield of sugar (%)	Tons cane per ton sugar	Average yield of sugar (tons. ac.)	Percentage (%)	S/A (cwt.	Super ac.)
H 54			PLANT CANES (B 34104)							
0	2½ ...	...	7.47	5.02	100	7.67	5.12	100	3	0
	5 ...	...	7.45	6.23	124	7.46	5.96	116	6	
	7½ ...	...	7.44	6.15	122	7.36	6.17	120	9	
3	2½ ...	...	7.53	5.21	104	**7.16**	5.59	109	3	3
	5 ...	...	8.34	5.47	109	7.76	6.64	130	6	
	7½ ...	...	7.54	0.88	137	7.74	6.17	120	9	
6	2½ ...	...	7.28	5.67	113	7.24	5.91	115	3	6
	5 ...	...	**7.17**	6.54	130	**7.13**	6.82	133	6	
	7½ ...	...	7.56	**7.55**	**150**	7.27	**7.62**	**149**	9	
9	2½ ...	...	7.24	5.58	111	7.20	6.04	118	3	9
	5 ...	...	**7.19**	5.95	119	7.57	6.80	133	6	
	7½ ...	...	7.47	**7.16**	**143**	7.43	**6.93**	**135**	9	
			FIRST RATOONS (B 34104)							
0	2½ ...	...	9.06	3.08	100	**8.01**	3.79	100	3	0
	5 ...	...	8.72	3.50	114	8.24	4.26	112	6	
	7½ ...	...	8.72	3.57	116	9.19	3.81	101	9	
3	2½ ...	...	8.23	3.96	129	8.24	3.90	103	3	3
	5 ...	...	**8.01**	4.64	151	8.31	4.44	117	6	
	7½ ...	...	8.14	**4.80**	**156**	8.41	4.15	110	9	
6	2½ ...	...	**7.99**	3.63	118	8.20	4.01	106	3	6
	5 ...	...	8.34	4.33	141	**8.09**	4.56	120	6	
	7½ ...	...	9.34	4.19	136	8.14	**4.85**	**128**	9	
9	2½ ...	...	8.46	3.74	121	8.57	3.69	97	3	9
	5 ...	...	8.11	4.55	148	8.53	4.53	119	6	
	7½ ...	...	8.14	**4.87**	**158**	8.21	**4.77**	**126**	9	
HO 53			PLANT CANES (B 34104)							
	4 ...	...	7.49	5.97	100	7.98	5.50	100	4	0
	8 ...	...	7.77	6.18	104	8.15	5.15	112	8	
	12 ...	...	8.18	4.37	73	7.68	5.35	97	12	
	16 ...	...	8.05	4.75	80	7.60	5.12	93	16	
	20 ...	...	7.66	6.29	105	7.88	4.98	91	20	
3	4 ...	...	7.74	6.79	114	7.40	6.26	114	4	3
	8 ...	...	7.41	7.89	132	7.95	7.59	138	8	
	12 ...	...	7.69	8.06	135	7.51	6.93	126	12	
	16 ...	...	7.49	8.36	140	7.89	7.05	128	16	
	20 ...	...	8.40	6.98	117	7.78	6.64	121	20	
6	4 ...	...	7.76	6.37	107	7.40	8.07	147	4	6
	8 ...	...	7.52	8.36	140	8.03	7.95	145	8	
	12 ...	...	7.85	8.22	138	7.53	8.37	152	12	
	16 ...	...	7.98	7.84	131	7.73	7.88	143	16	
	20 ...	...	7.99	7.09	119	7.51	**8.55**	**155**	20	
9	4 ...	...	**7.32**	7.96	133	**7.14**	7.70	140	4	9
	8 ...	...	7.57	**8.40**	**141**	7.63	7.89	143	8	
	12 ...	...	7.63	7.77	130	**7.05**	**8.40**	**153**	12	
	16 ...	...	**7·37**	**9.12**	**153**	8.31	8.00	144	16	
	20 ...	...	8.10	6.92	116	7.97	7.56	137	20	

(No data obtained for first ratoons).

In the columns for tons of cane per ton of sugar in Table IV., the two largest values are printed in thick type, and in the columns for sugar yields, tons per acre and percentage, the two highest values are also similarly indicated. The tabulated data show very clearly that low tonnages of cane required to make a ton of sugar, depending on *juice purity,* are generally associated with high phosphate treatments, most commonly 6 or 9 cwt. of superphosphate per acre. There is no evidence that high phosphate-high nitrogen manuring produces sugar-cane having juice of low purity; on the contrary, the high phosphate treatments seem definitely to produce high-purity juices.

The data also demonstrate that the optimum phosphate-nitrogen manurial combination produces about 50 per cent. more sugar from plant-canes, B 34104 variety, grown on Red Soil, than the routine estate treatment. In one experiment, the percentage increment was just as large for first ratoons. No significant benefit from liming is indicated by the data. It is not intended to discuss the reasons for this last finding until the lime status of the soil has been fully examined so as to ascertain whether or no the added limestone has completely reacted with the soil.

PART V

Field Experience with High Phosphate—High Nitrogen Fertilizer Treatment

In this section, the yield results of some preliminary trials on a commercial field-scale with high phosphate—high nitrogen fertilizer treatment are compared with those obtained with the routine estate manurial practice (3 cwt. of ammonium sulphate per acre). Two plant-cane fields on Red Soil and two on Black Soil were given a high phosphate-high nitrogen treatment (6 cwt. superphosphate and 8 cwt. ammonium sulphate per acre) while two adjacent fields, having the same soils and receiving the same cultivation, were treated according to routine estate practice. The results are given in Table V.

The treatment of 6 cwt. superphosphate and 8 cwt. ammonium sulphate per acre was responsible for an average increment in plant-cane yield of 17.5 tons per acre, or 51.2 per cent. of the yield obtained from the routine estate fertilizer treatment for Red Soil, and 16.6 tons per acre, or 32.4 per cent. of that obtained from the routine estate fertilizer treatment for Black Soil.

Costs: The nett profit resulting from the high phosphate-high nitrogen treatment over routine estate practice amounted to 40 dollars per acre on Red Soil and 36 dollars per acre on Black Soil. These results of preliminary commercial field trials have thus substantiated those obtained in the plot experiments.

TABLE V

YIELDS FROM PLANT-CANE FIELDS REAPED IN 1946 CROP

High phosphate-high nitrogen (6 cwt. superphosphate + 8 cwt. ammonium sulphate per acre)				Routine estate treatment (3 cwt. ammonium sulphate per acre)			
Field No.	Acreage	Tons of cane reaped	Tons of cane per acre	Field No.	Acreage	Tons of cane reaped	Tons of cane per acre
		RED SOIL :—B 34104 : PLANT-CANE, 1946 CROP					
H. 103 ...	5.9	260.9	44.1	H.51	10.8	249.2	23.0
G.C. 26 ...	14.2	779.2	54.8	G.C. 28	25.2	982.9	38.9
Total ...	20.1	1040.1	51.7	Total ...	36.0	1232.1	34.1
		BLACK SOIL : B 34104 : PLANT CANE, 1946 CROP					
R.8D ...	4.4	299.5	67.3	R.8C	10.2	416.8	40.8
B.V.4 ...	7.1	480.5	68.1	B.V.3	30.3	1658.5	54.7
Total ...	11.5	780.0	67.8	Total ...	40.5	2075.3	51.2

VALUE OF INCREMENTS IN YIELD OF CANE PER ACRE FROM 6 CWT. SUPERPHOSPHATE 8 CWT. AMMONIUM SULPHATE, PER ACRE

	Increments in tons of cane per acre	Value at $5.50 per ton of cane	Extra costs per acre involved	Nett profit per acre (dollars)
Red Soil	17.5 tons	$ 96.3	$ 56.3	$ 40.0
Black Soil	16.6 tons	91.3	55.2	36.1

Visible above-ground effects: The accompanying photographs convey some idea of the visible differences of growth in fields given the routine estate treatment and that in fields given the high phosphate-high nitrogen treatment. These photographs were taken in a trace separating two fields, W.29, and W.31, in Picton Estate belonging to the Ste. Madeleine Sugar Company. Each field received similar cultivations and grew the same cane variety, planted at the same time. In photograph 1, Field W.29, shown on the left of the pictrue, received routine estate treatment while W.31, on the right, received 6 cwt. of superphosphate and 8 cwt. of ammonium sulphate per acre. Photograph 2 was taken in the trace looking into Field W.29, and photograph 3 looking into Field W.31. Photographs 4 and 5 show the type of growth and dimensions of the individual cane-stools in Fields W.29 and W.31 respectively.*

Effect on the commercial production of sugar-cane at Ste. Madeleine: It has been shown that, on an experimental basis, the nett profit from high phosphate-high nitrogen treatment, over and above that given by the routine estate practice, averages 38 dollars per acre for plant-canes and 20 dollars per acre for ratoons. If this were realised over the entire estate acreage to be reaped at Ste. Madeleine during the 1947 crop, the following financial benefits might be expected, taking the value of cane as 5.50 dollars per ton, delivered at the factory.

Acres for reaping 1947

Plant canes 2677 acres @ $38	=	$ 101,626
Ratoon canes 7059 acres @ $20	=	$ 141,180
Total	=	$ 242,806
		£ 50,585

Various factors, such as time of planting, weather, soil variation, age and variety of cane, would, perhaps preclude the full realisation of such a large financial return, but the obvious benefits within reach through the application of the new fertilizer treatment, based on the results of the investigations herein recorded, demand serious consideration. At Ste. Madeleine, the high phosphate-high nitrogen fertilizer policy is rapidly replacing the previous routine practice, but the rate of replacement is governed by fertilizer supply, which at present is inadequate. Applications varying from 3 cwt. of superphosphate and 3 cwt. ammonium sulphate per acre to 6 cwt. of superphosphate and 8 cwt. of ammonium sulphate per acre were actually applied to 26 per cent. of the total acreage for reaping during the 1947 crop season. Fifty-seven per cent. of the acreage of this crop at the time of writing (March, 1947) had been harvested. The following is the comparative yield returns of the 1946 and 1947 crops at the same stage of each crop with 57 per cent. of the total acreage reaped.

Crop	Acreage distribution of total acreage reaped at 57% of crop		Per cent. acreage treated with Super + S/A, of total acres to reap	Yield return per acre (tons cane)
	Plant-canes	*Ratoons*		
1946	26%	74%	0.5%	23.4
1947	34	66	26.0	27.5

With 26 per cent. of the total acreage to reap in 1947, that has been treated with high phosphate —high nitrogen, the yield return shows an all-round increment of 4 tons of cane per acre. At the present 1947 average quality-ratio of 9.42 tons of cane needed to make one ton of sugar, this amount of cane is equivalent to a yield of 0.42 tons of sugar per acre. The varying rates of phosphate and nitrogen applications to the 26 per cent. of the total acreage to reap is equivalent to approximately one cwt. per acre of superphosphate and one cwt. per acre of ammonium sulphate, in addition to the regulation 3 cwt. per acre application of ammonium sulphate over the total acreage. For the total acreage of 9,736 acres to be reaped at Ste. Madeleine during the 1947 crop the sugar equivalent of the extra cane would be more than 4,000 tons.

Other benefits resulting from the investigational work include the elimination of inferior quality cane, such as Uba and Coimbatore varieties, which were exclusively grown in the past on Red Soil. This type of cane is detrimental to the milling plant and to sugar production generally. These varieties are now being replaced by the best seedling canes which are producing excellent returns on Red Soil by virtue of the application of high phosphate-high nitrogen fertilizers. The progress in replacement is indicated below.

Approximate percentage of total acreage to reap

Crop:	*Noble canes*	*Thin-stemmed canes (Uba and Coimbatore)*
1944	46 per cent.	54 per cent.
1945	47 „	53 „
1946	54½ „	45½ „
1947	10 „	30 „

It is anticipated that the total elimination of Uba and Coimbatore varieties will have been achieved by 1949.

* The yield results obtained at harvesting from these fields were as follows :—Field W. 29, 40.0 tons cane per acre, and Field W. 31, 54.9 tons cane per acre. This represents an increase in yield of 37½ per cent. due to high phosphate-high nitrogen treatment.

EFFECTS OF HIGH PHOSPHATE-HIGH NITROGEN TREATMENT

RED SOIL : PICTON ESTATE : STE. MADELEINE

PHOTO 1 : *Left* : Field W. 29 : Plant canes, B.34104, 23 weeks old. 3 cwt. S/A
Right : Field W. 31 : Plant canes, B.34104, 23 weeks old. 6 cwt. Super. + 8 cwt. S/A

PHOTO 2 : Field W. 29 : 3 cwt. S/A.

PHOTO 3 : Field W. 31 : 6 cwt. Super + 8 cwt. S/A

EFFECTS OF HIGH PHOSPHATE-HIGH NITROGEN TREATMENT

RED SOIL : PICTON ESTATE : STE. MADELEINE

PHOTO 4 : Average stool of cane (17 tillers) Field W. 29

PHOTO 5 : Average stool of cane (22 tillers) Field W 31

Statistical treatment of results: The yield data obtained in the four large-scale field manurial experiments described in the preceding sections were treated by Fisher's Analysis of Variance method (10). The larger increment values recorded in the text are practically all statistically significant. Lack of space precludes the publication of the full tables of data and the statistics calculated from them. These are accessible in the office of Ste. Madeleine Sugar Company, where they may be consulted by anyone interested in the actual method of treatment of the experimental results.

Summary

1. This article presents some striking experimental results recently obtained with high dosages of superphosphate applied in combination with high dosages of ammonium sulphate to Red Soil (Tropical Red Podzolic Clay) and to Black Soil (Rendzina) which comprises most of the lands of the Ste. Madeleine Sugar Company's estates in South Trinidad.

2. Previous field experiments had demonstrated that the optimum dressing of ammonium sulphate, applied with or without small nominal amounts of superphosphate and potassium sulphate, was 3 cwt. per acre. Yield increments up to 63 per cent. could thus be obtained on Red Soil in which only thin canes, such as Uba and Co 213, could profitably be grown, though the maximum average yield was still relatively low, namely about 20 tons per acre. For Black Soil growing "noble" canes (such as BH 10/12), increments up to 24 per cent. could be obtained; the maximum average yield for this variety on this soil was around 30 tons per acre. With POJ 2878, increments up to 66 per cent. have been recorded for Black Soil, with maximum average yield around 34 tons per acre.

3. Following the publication of the results of chemical tests and the Mitscherlich pot-test obtained at the Imperial College of Tropical Agriculture, Trinidad, with representative samples of Ste. Madeleine Red Soil and Black Soil which had demonstrated high phosphate deficiency as well as high nitrogen deficiency in both these soil-types, six new series of fertilizer experiments were laid down in which graded dosages of superphosphate up to 9 cwt. per acre, and of amonium sulphate up to 7½ or 9 cwt. in one series and up to 20 cwt. per acre in another, were applied. In one series on Red Soil, lime was also applied. Another series was laid down on Black Soil that had suffered deep erosion, exposing the calcareous soil parent material.

4. The average maximum experimental field response to high dosages of superphosphate and ammonium sulphate over yields given by routine estate manurial treatment was of the order of 40 per cent. on weight of sugar-cane, with average nett profit of 45 dollars per acre for plant-canes and about 20 dollars for first ratoons.

Greatest response was shown by eroded Black Soil (60 per cent.) which implies that wasted black lands may be renovated by appropriate manurial treatment involving high phosphate dressings.

5. Maximum yields of 60 tons per acre on Red Soil and 80 tons per acre on Black Soil with plant-canes (B 34104) and 43 tons per acre on both soils with first ratoons, were obtained from the high dressings. Liming apparently conferred no extra benefit on Red Soil; this result requires further examination.

6. Yield responses from the high phosphate manuring were traced to a large increase in the number of tillers produced.

7. The production of sugar per acre, calculated from cane yields and juice analyses, showed that high phosphate treatment improves juice quality and thus diminishes the number of tons of cane needed to make a ton of sugar.

8. Some results are given for actual field performances with high phosphate-high nitrogen manuring carried out since the plot experiments were completed. They show that the increments in yield obtained by the new treatment are sustained on a field scale, both for Red Soil and for Black Soil. Nett profits of 40 and 36 dollars per acre were realised over acreages of 20 and 12 acres respectively with the new treatment as compared with the routine fertilizer practice involving ammonium sulphate alone.

9. Based on the results so far obtained, it is shown that a high phosphate-high nitrogen manurial policy for the Ste. Madeleine estates would yield large profits, of the order £50,000 (pounds) a year from about 10,000 acres of plant and ratoon canes reaped. So far, with only 26 per cent. of the area receiving the new treatment, the sugar equivalent of the extra cane tonnage produced in the 1947 crop will be more than 4,000 tons.

10. Under the new high phosphate-high nitrogen manurial policy, thin-stemmed sugar-cane varieties (such as Uba and Coimbatore) will soon be entirely replaced on Red Soil by the best seedling "noble" canes.

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SOIL SURVEYS IN THE CARIBBEAN AREA

The West Indies Conference, Second Session, which met in St. Thomas, Virgin Islands of the United States, in February-March, 1946, considered among other matters the question of soil surveys in the Caribbean Area. Its recommendation to the Caribbean Commission is recorded in paragraphs 29-21 of the report of Committee III. and is as follows :—

"29. The number of qualified soil scientists in the Caribbean is extremely limited and a formal conference would at present be of little advantage. We suggest, however, that an early informal meeting in Puerto Rico would be of immediate practical benefit in order that nomenclature and methods may be standardized as far as possible for the purposes of a regional soil survey.

30. We accordingly recommend that the Caribbean Commission convene an informal meeting of soil scientists nominated by the governments of the Caribbean territories, together with soil scientists of the United States Department of Agriculture, in particular those who took an active part in the survey of Puerto Rico, and soil scientists from other metropolitan governments, should they wish to be represented. Such a meeting should take place in Puerto Rico at an early date.

31. We believe that the soil scientists attending this informal meeting may well consider and offer recommendations regarding the desirability of a formal conference at a later date for the purpose of developing a regional programme of soil surveys."

With the object of obtaining advice on the recommendation, the Caribbean Commission, of which the West Indian Conference is an auxiliary body, recently appointed a sub-committee of soil scientists representative of French, Netherlands, British and United States territories of the Caribbean and comprising :—Mr. H. J. Page, Principal of the Imperial College of Tropical Agriculture, Trinidad (Chairman), Mr. D. Blanche, Acting Head of the Agricultural Service, Martinique; Dr. J. A. Bonnet, Head of the Soils Department, Agricultural Experiment Station of the University of Puerto Rico; Mr. F. Hardy, Professor of Chemistry and Soil Science, Imperial College of Tropical Agriculture, Trinidad; Dr. H. J. Muller, Agricultural Chemist, Department of Agricultural Economics, Surinam.

The sub-committee met in Trinidad from 15th to 18th March, 1947. Excursions were arranged by Professor Hardy to demonstrate typical soils in relation to local geological, lithological and topographical conditions and to local crops; and also in relation to soils elsewhere in the Caribbean region. The laboratory methods in use at the Imperial College were also demonstrated.

The sub-committee recommended that a Conference of Soil Scientists should be held in Puerto Rico in 1948, under the auspices of the Committee on Agriculture, Nutrition, Fisheries and Forestry of the Caribbean Research Council, for the purpose of studying systems and methods of classification and mapping of tropical soils, with special reference to the standardization of such systems and methods for use in soil surveys throughout the Caribbean region and to carrying out such surveys as soon as possible. The proposed agenda is :—

(i) Presentation and discussion of collected data on soil forming factors of the various territories.

(ii) Standardization of field and laboratory method of soil surveys.

(iii) Discussion of different systems of soil classification and mapping.

(iv) Formulation of a detailed regional programme of soil surveys.

(v) Survey of problems of soil erosion, soil conservation and soil renovation in the different territories.

(vi) Practical application of soil surveys to land utilization.

The intention is that papers on these subjects should not be read at, but be distributed to participants well in advance of the conference, at which they would be briefly introduced by the authors as a prelude to general discussion.

It was also recommended that attendance at the conference should be as representative as possible and should include soil scientists, who are specially interested in tropical soils from the above-mentioned points of view, not only from the Caribbean, but also from other countries. In this connection special reference was made to Cuba, Haiti and the Dominican Republic and it was recommended that the Governments of these countries should be invited to send representatives to participate in the conference.

The recommendations have since been approved by the Caribbean Commission and a working committee has been set up to prepare for the conference, the date of which has not yet been definitely fixed.